

## APPLICATIONS

- Optical beam chopper/shutter
- Optical element positioning
- Vending machine actuator
- Office equipment actuator
- Air damper/door actuator
- Automobile actuator
- Fluid valve actuator

## FEATURES AND BENEFITS

- Wide angle, bidirectional rotation
- Linear angle vs. current profile
- Low power consumption
- Convenient package size
- Industry-standard shaft size (0.118 inches / 3.0 mm)
- Two coils, individually accessible for flexible drive
- Low rotor inertia allows responsive control of common loads
- Connectorized electrical interface for easy installation
- Front and internal rear shafts allow encoder/position sensor use
- Disk-drive quality, radially-preloaded ball bearings for long life
- Smooth, quiet, shock-free motion (no clack-clack at end of travel)
- Magnetic spring return (fail safe - no torsion bars to wear out or break)
- True rotary motion with no axial displacement



## GENERAL DESCRIPTION

The VRAD 516 actuator is a limited rotation Versatile Rotary Actuator Device featuring a magnetic spring return, very wide-angle capability, and linear angle-versus-current profile. The high coil resistance allows for low power consumption, and access to two individual drive coils allows flexible single-supply unidirectional or bidirectional operation as well as dual-supply operation. An internal rear shaft allows for use of an encoder or position sensor for closed loop operation.

## ORDERING INFORMATION

The part number provided below is for our standard VRAD-516 actuator. Customization is possible. For additional information, see the datasheet section on Part Numbering Scheme.

Device part number	Comment
VRAD-0x5x16-0.27-1.35-2x25-12.6-118x0.24-118x0.24-D-C	Standard product



## Versatile Rotary Actuator Device VRAD 516 series

(patents pending)

### SPECIFICATIONS

Parameter	Value	Units
Rotation angle <sup>(1)</sup>	+/- 45	Mechanical degrees peak-to-peak
Torque Factor <sup>(2)</sup>	270,000	Dyne*Centimeters per amp (coils in series)
Magnetic Spring Stiffness <sup>(3)</sup>	1,350	Dyne*Centimeters per degree
Rotor Inertia	0.036	Gram*Centimeters <sup>2</sup>
Natural Frequency <sup>(4)</sup>	240	Hz
Coil Resistance <sup>(5)</sup>	50	Ohms (coils in series)
Coil Inductance <sup>(5)</sup>	12.6	MilliHenry at 1kHz (coils in series)
Maximum Current <sup>(6)</sup>	0.5	Amp per coil
Angle vs. Current Linearity	90	% over +/- 45 degrees peak-to-peak
Angle vs. Current Sensitivity <sup>(7)</sup>	5	Milliamps per degree (coils in series)
Temperature coefficient of sensitivity	+0.14	% per °C
Angular position hysteresis	+/- 1	Mechanical degrees maximum
Maximum internal temperature <sup>(8)</sup>	80	°C
Thermal Resistance with heatsink <sup>(9)</sup>	2.8	°C per watt
Thermal resistance without heatsink	28	°C per watt
DC Power at +/- 20 degrees	0.5	Watts (5 volts series; 2.5 volts parallel)
DC Power at +/- 40 degrees	2.0	Watts (10 volts series; 5 volts parallel)
DC Power at +/- 60 degrees	5.12	Watts (16 volts series; 8 volts parallel)
Dielectric Strength	1000	VRMS
Life cycles <sup>(10)</sup>	10 <sup>10</sup>	Cycles
Mass	30	Grams

### NOTES

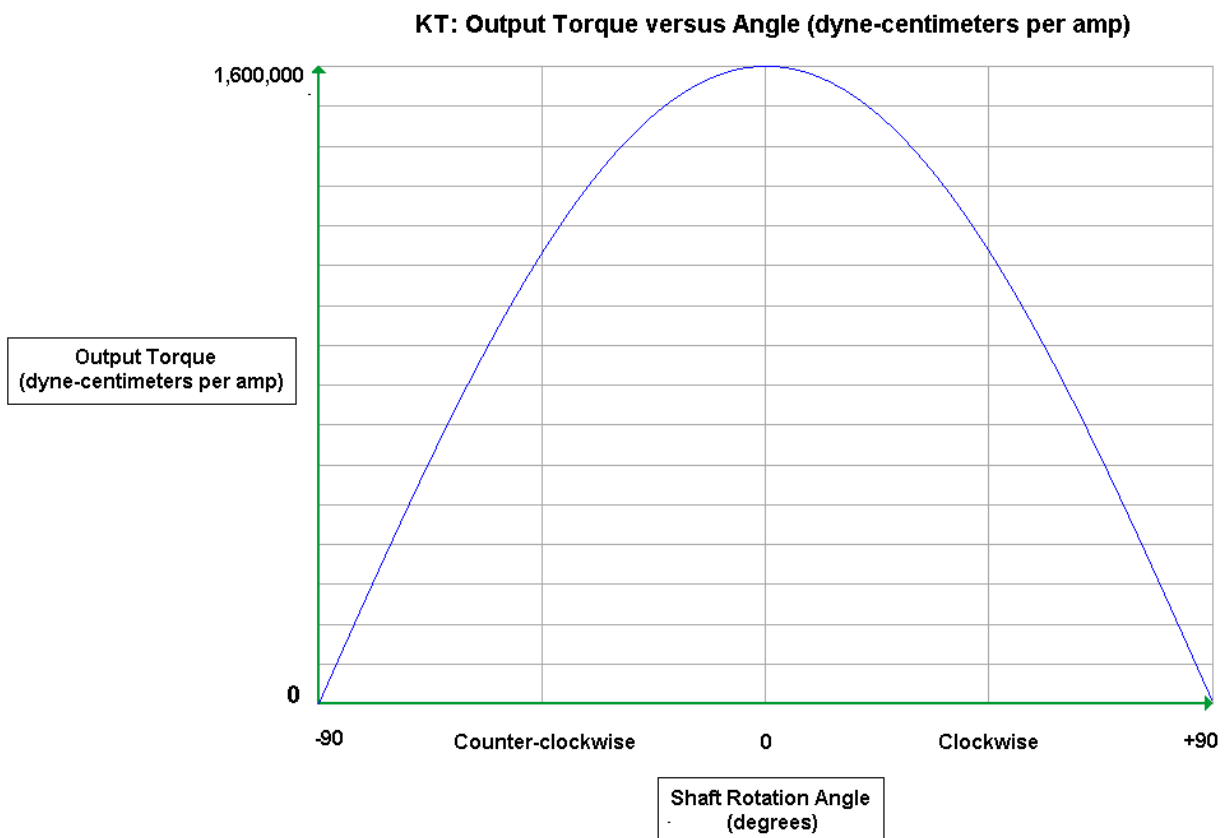
1. There is no mechanical stop mechanism preventing further rotation, and the actuator may be used with angles greater than +/- 60 mechanical degrees with some sacrifice in angle-versus-current linearity.
2. Torque Factor depends on the shaft rotation angle. See the section on Torque production.
3. Magnetic spring stiffness depends on the shaft rotation angle and the model of the actuator. See the section on Magnetic Spring Return.
4. Since Magnetic Spring Stiffness depends on angle, Natural Frequency also has some minor dependence on angle. Natural frequency is thus specified for small angles.
5. Coil resistance and inductance depend on whether coils are connected in series, in parallel, or used independently. See the section on Coil Resistance and Inductance.
6. It is not recommended to operate the actuator continuously with greater than 0.2 amps per coil without a heat sink.
7. Angle vs. Current operation assumes that there is no static load and that the actuator is merely used to move a flag, mirror, or other element suspended from the actuator shaft.
8. The actuator should survive operation over 100 degrees C, but it is not recommended to exceed 80 degrees C on a repeated basis.
9. Heat sink must be clamped around the actuator to meet the specification above.
10. Life cycles are only limited by bearing life. Bearings are high quality disk drive grade.

Specifications are at a temperature of 25° C. All mechanical and electrical specifications are +/-10%.

## TORQUE PRODUCTION

Torque is produced by passing current through one or both actuator coils. Within the actuator, both coils are the same and thus, both contribute equally to torque production. Moreover, current passed through the combination of both coils will produce the same torque as twice the current passed through a single coil. (In other words 100mA flowing through both coils will produce the same torque as 200mA flowing through a single coil.)

The actuator produces the maximum amount of torque at its central, rest position, to which we refer as “zero degrees”. In this position the torque produced is approximately 270,000 Dyne\*Centimeters per Amp of electrical current. As the shaft is rotated away from the central resting position, torque production is reduced, and is approximately proportional to the cosine of the rotation angle. For example, at +/-10 degrees, the torque produced is 98.5% of the original torque. At +/-20 degrees, the torque produced is 94% of the original torque. At +/-45 degrees, the torque produced is 70.7% of the original torque. See the graph below, which illustrates the shape of the torque factor as a function of rotation angle. (Note that the actual torque values shown in the graph are for our larger VRAD-1510 actuator.)



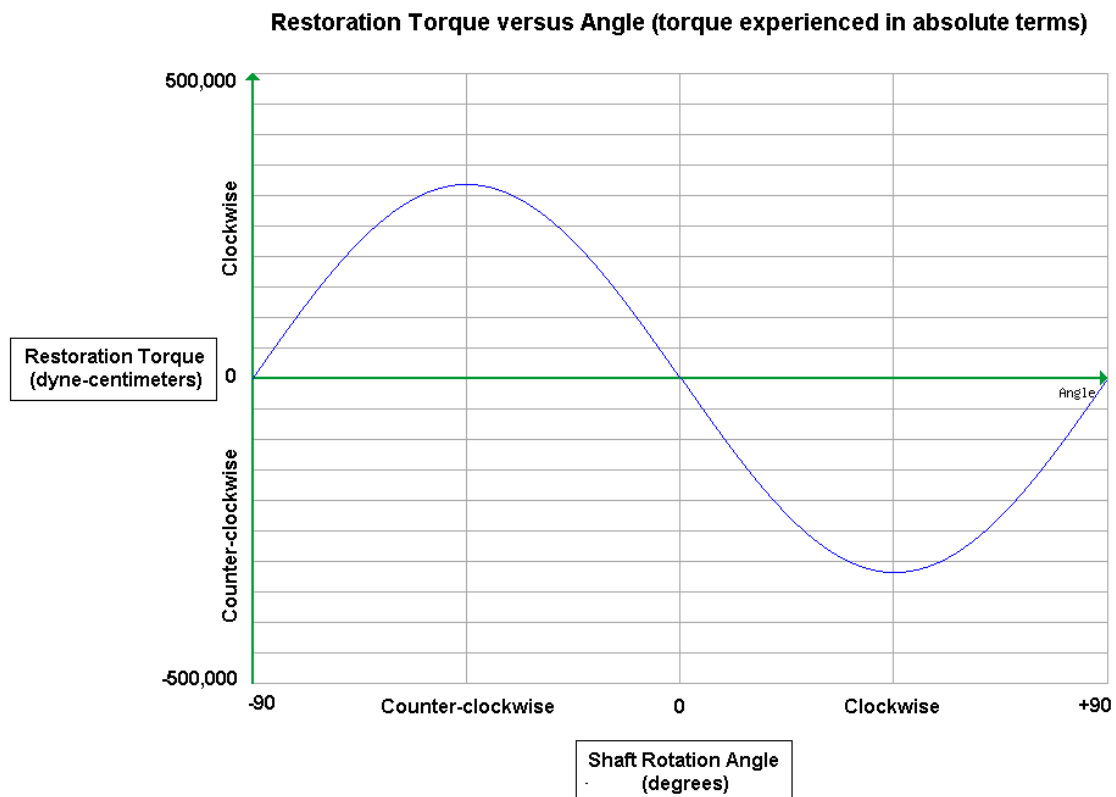
Torque can be produced in a clockwise and counter-clockwise direction, depending on shaft orientation and current direction. Since the words “clockwise” and “counterclockwise” are actually relative terms and not absolute (i.e. clockwise when viewed from the front is the opposite of clockwise when viewed from the rear), and since the actuator rotation direction depends on the initial magnetic orientation of the actuator, a brief test is needed to determine the rotation direction. If the rotation is opposite of that desired, simply

rotate the shaft 180 degrees which will reverse internal phenomenon and cause rotation in the opposite direction.

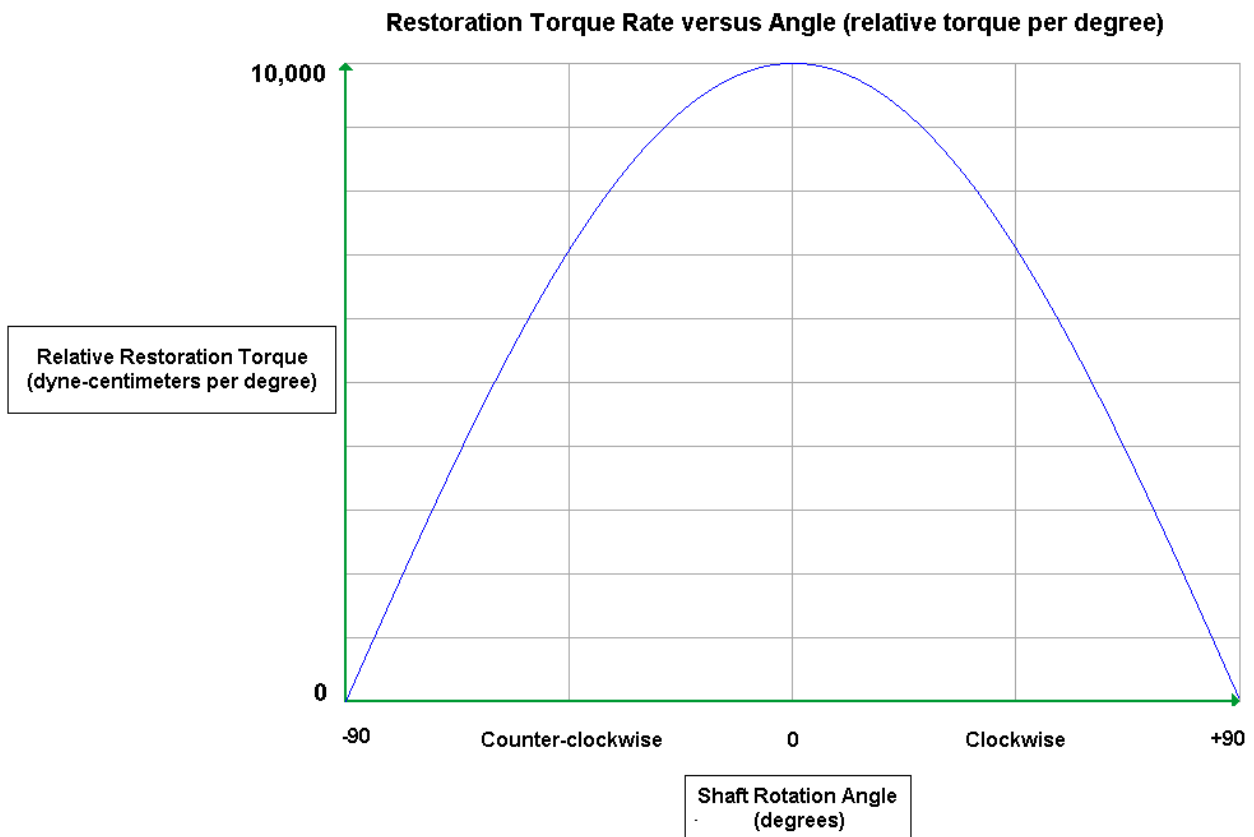
## MAGNETIC SPRING RETURN

The actuator features a magnetic spring return, which provides torque in the direction that will restore the rotor to its central resting position. There are two ways to describe the restoration torque – in absolute terms, or in relative terms.

In absolute terms, the magnetic spring return is providing zero torque when the rotor is in its central resting position. As you rotate the shaft clockwise a few degrees, the magnetic spring return will produce torque in a counterclockwise direction. As you rotate the shaft a few degrees more, the magnetic spring return will produce even more torque. Torque produced by the magnetic spring return tends to be approximately sinusoidal in nature, and is at its maximum when the rotor is in the  $\pm 45$  degree positions. Further rotation of the shaft beyond  $\pm 45$  still produces a restoration torque, but the amount of torque decreases until the shaft is in the  $\pm 90$  degree positions, at which point no restoration torque is provided by the magnetic spring return. The graph below illustrates the shape of the restoration torque in absolute terms. (Note that the actual torque values shown in the graph are for our larger VRAD-1510 actuator.)



There is another way to describe the magnetic spring return, and that is in relative terms – dyne centimeters of torque per degree of rotation, which may also be called “spring rate”. If you rotate the shaft clockwise by 1 degree, the restoration torque is approximately 1,350 Dyne\*Centimeters. If you rotate the shaft clockwise by 2 degrees, the restoration torque is approximately 2,700 Dyne\*Centimeters. If you rotate the shaft by 10 degrees, the restoration torque is approximately 13,500 Dyne\*Centimeters. Thus, in relative terms, the restoration torque (spring rate) is approximately 1,350 Dyne\*Centimeters per degree for small angles. As the angle increases, the restoration torque per degree decreases, and is approximately proportional to the cosine of the rotation angle. For example, at +/-10 degrees, the restoration torque spring rate is 98.5% of the original rate. At +/-20 degrees, the torque spring rate is 94% of the original rate. At +/-45 degrees, the torque spring rate is 70.7% of the original rate. See the chart below, which illustrates the shape of the restoration torque in relative terms. (Note that the actual torque values shown in the graph are for our larger VRAD-1510 actuator.)



Note that we can modify the amount of restoration torque produced by the magnetic spring return and thus, actuators can be manufactured which produce the same torque, but have reduced magnetic spring return action. Such actuators will provide a greater amount of rotation with less input electrical current. This may be desirable in low power applications. Likewise, magnetic spring return can be increased as well.

## COIL RESISTANCE AND INDUCTANCE

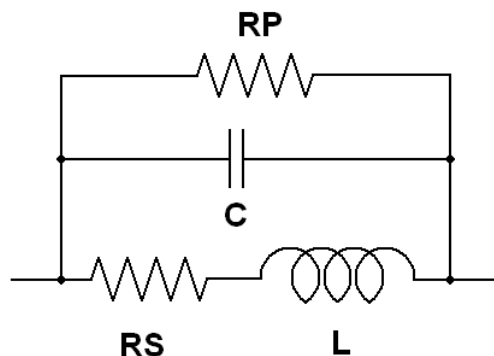
Each coil has a resistance of approximately 25 ohms. The series combination of coils has a resistance of approximately 50 ohms. Thus, applying 5 volts to the series combination of coils will consume only 100mA of current.

Each coil has an inductance of approximately 4 millihenry, but this will only be observed if one coil is used and one coil is completely disconnected. There is strong mutual inductance between the two coils, and short circuiting the second coil will reflect an inductance in the first coil of 3.4 milliHenry at 1kHz. Due to the mutual inductance between the two coils, the series combination of coils has more than three times the inductance of a single coil, not twice the inductance as would be the case with two inductors having no mutual inductance. Thus, the inductance of the series combination of two coils is 12.6 milliHenry at 1kHz. The parallel combination of two coils is 3.2 milliHenry at 1kHz.

Note that within this actuator design, the inductance does not change very much as the rotation angle is changed, and thus, there is very little “inductance modulation”.

## EQUIVALENT CIRCUIT

The equivalent circuit of the actuator with two coils connected in series is shown below.



RS is the series resistance of the copper coils

L is the inductance of the magnetic circuit

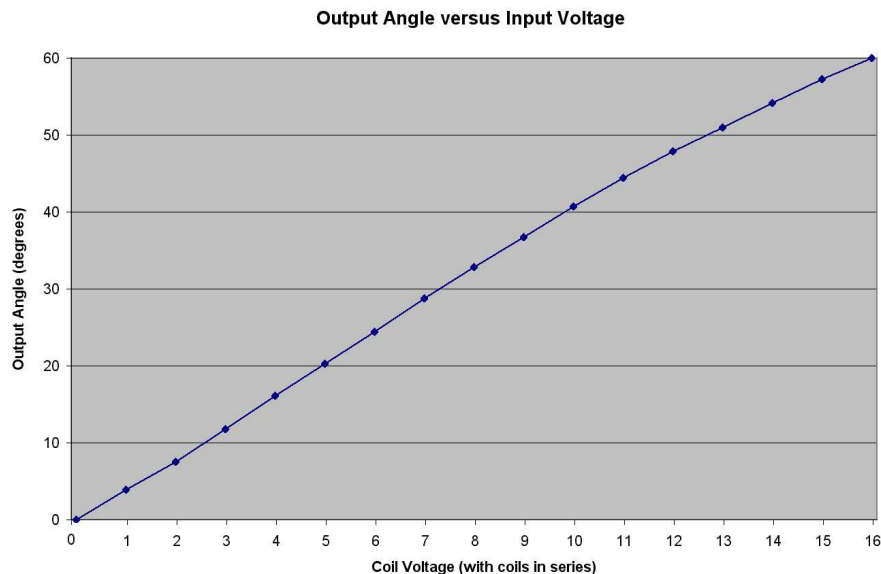
C is the capacitance caused by the layers of wire that form the coils

RP is the equivalent parallel resistance caused by the interaction of the coil and actuator materials

For the standard VRAD-516 actuator, the values are: RS = 50  $\Omega$ ; L = 12.6 mH; C= 1.3pF; RP = 90K  $\Omega$ .

### ACTUATOR LINEARITY AND SENSITIVITY

Since the torque versus angle profile is approximately proportional to the cosine of rotor angle, and also since the magnetic spring restoration torque versus angle profile is also approximately proportional to the cosine of rotor angle, these two cosines curves cancel out (as long as there is no static load on the rotor). Because of this, the angle versus current profile for this actuator is nearly linear, even over very large angles greater than +/- 45 degrees! The graph below shows actual measured linearity at various coil voltages.



With the coils connected in series and no static load attached to the shaft, the coil resistance is approximately 50 ohms, and motion provided is approximately 4 degrees per volt, resulting in the following:

- 20 degrees at 5 volts (100mA; 0.5 watts)
- 40 degrees at 10 volts (200mA; 2.0 watts)
- 60 degrees at 16 volts (320mA; 5.12 watts)

With the coils connected in parallel, the coil resistance is approximately 12.5 ohms, and motion provided is approximately 8 degrees per volt, resulting in the following:

- 40 degrees at 5 volts (400mA; 2.0 watts)
- 60 degrees at 8 volts (640mA; 5.12 watts)

Angles stated above are in EACH DIRECTION, not the peak-to-peak value of both directions.

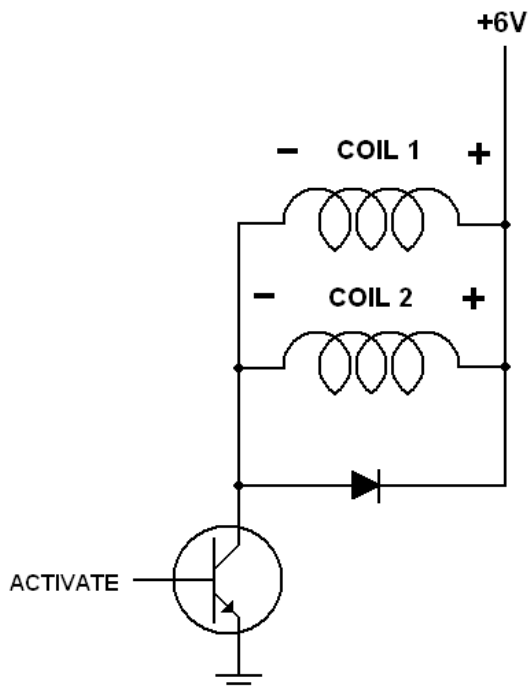
### SENSITIVITY DEPENDENCE ON TEMPERATURE

As the internal temperature of the actuator rises, the flux density produced by the magnet decreases. This reduces the magnetic spring return effect faster than it reduces the torque factor. As a result, the angle versus **current** actually increases a bit (at a rate of 0.14% per degree C) as temperature increases. However, the resistance of the copper coil increases faster than the magnetic phenomenon, and thus the angle versus **voltage** decreases a bit (at a rate of 0.32% per degree C) as temperature increases. Therefore the angular sensitivity versus temperature will depend on whether the actuator is driven with a pure current or with a pure voltage.

### ACTUATOR DRIVE TECHNIQUES

Since the VRAD-516 actuator has two coils which each have a relatively high resistance, this provides great flexibility in driving the actuator. Below you will see several drive techniques described, but there are certainly other possibilities as well. The techniques below are analog in nature, but digital (i.e. PWM) drive is also of course possible.

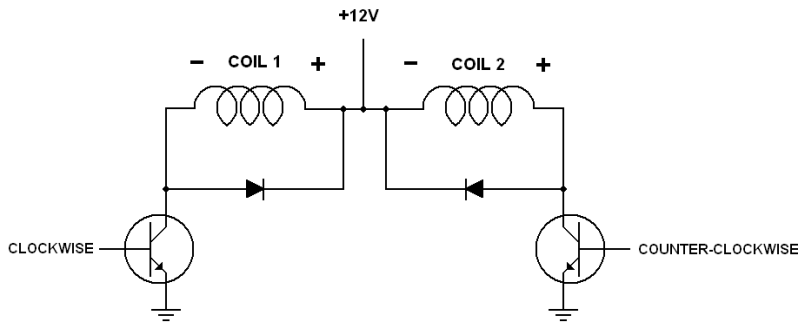
#### Single voltage, two-position (unidirectional actuation)



The circuit above shows a simple way to activate and deactivate the actuator, for example, in a shutter application. When the transistor conducts, voltage is supplied to the actuator, and it will rotate the shaft in an amount that depends on the supply voltage. When the transistor does not conduct, current is removed and the actuator shaft rotates back to its rest position. Here the coils are shown connected in parallel, but they may also be connected in series. The choice of parallel or series depends on the supply voltage and current, and desired rotation angle. The transistor can be replaced by a FET, relay, or switch. A diode is placed across the coil to limit inductive kick-back and motor back EMF from exceeding the supply voltage. The diode can be replaced by a series R/C snubber network if desired. Note that since only a single “switch” is used, only two positions are possible: actuated, and de-actuated.

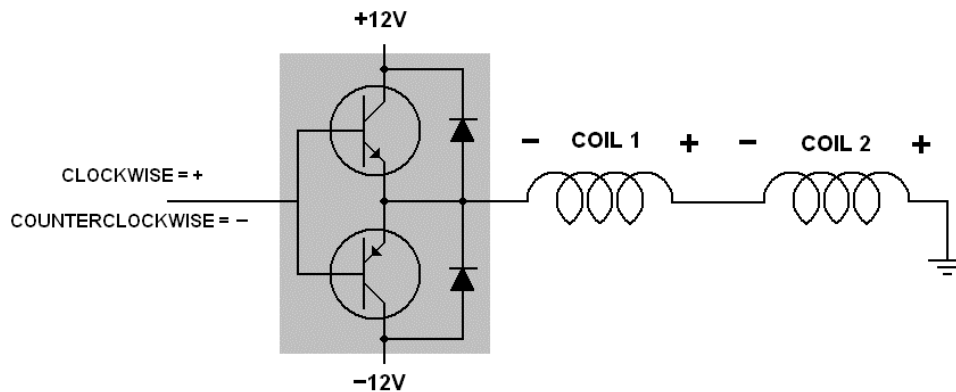


### Single voltage, three-position (bidirectional actuation)



The circuit above shows a simple way to command the actuator to rotate either clockwise or counterclockwise. When the left-most transistor conducts, voltage is supplied to one coil in the actuator, which (depending on shaft orientation) may force the actuator to rotate clockwise. When the right-most transistor conducts, voltage is supplied to another coil in the actuator which may force the actuator to rotate counterclockwise. When neither transistor conducts, current is removed and the actuator shaft rotates back to its central rest position. The amount of rotation is dictated by the supply voltage. As was the case above, the transistor can be replaced by a FET, relay, or switch. A diode is placed across each coil to limit inductive kick-back and motor back EMF from exceeding the supply voltage. The diode can be replaced by a series R/C snubber network if desired.

### Dual voltage, variable position (bidirectional actuation)



The circuit above shows a way to accomplish variable position control. Here two supply voltages feed transistors which then supply voltage to the actuator. The amount of voltage supplied by the transistors will dictate the angle and direction of the actuator. The transistors and diodes in the shaded area may be implemented as a Power Op-amp. Note that variable position is also possible with a single supply, using an H-Bridge technique. In such a case, four transistors (or two Power Op-amps) are used, and the actuator coil is connected between the two. Here the coils are shown connected in series, but they may also be connected in parallel. The choice of parallel or series depends on the supply voltage and current, and desired rotation angle.



## Versatile Rotary Actuator Device VRAD 516 series (patents pending)

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### Using one coil for drive, and the second for velocity or damping control

Since both coils offer the same torque production capability, and since a single coil offers the same torque capability as two coils (albeit at twice the current), this raises the possibility that one coil may be used for a purpose other than torque production, such as for velocity sensing or dynamic braking. For example, a resistor may be connected across the second coil and the value of the resistor may be adjusted to control the amount of dynamic braking (damping). Note that when using the second coil for velocity sensing, drive current in the first coil will need to be electronically removed, due to the strong mutual inductance between the two coils.



## SHAFT USAGE

The actuator features a front shaft and rear shaft. However, on the VRAD-516, the rear shaft is contained within the rear portion of the actuator housing. A position sensor may be mounted in the rear portion. Please contact us if you are interested in this option.

As mentioned above, there is a magnetic return spring that is a feature of this actuator. Although this magnetic spring return provides torque that tends to rotate the rotor back to a central rest position, there is nothing preventing the shaft from being rotated all the way around. In fact this could be a benefit. Two actuators may be used together and shafts can be oriented 90 degrees to one another, forming a two-phase continuous rotation motor.

Nevertheless, if the possibility of continuous rotation is not desired, and if you are driving heavy inertial loads over angles greater than approximately  $\pm 40$  degrees, and if you are driving those heavy inertial loads very quickly, it may be necessary to implement an external stop mechanism. Such a mechanism may be attached to one of the shafts.

Note that standard VRAD-516 actuator features a radial preload, facilitated as a part of the magnetic circuit.



## Versatile Rotary Actuator Device VRAD 516 series (patents pending)

### PART NUMBERING SCHEME

The part numbering scheme was developed as a tool for customers to completely specify individual actuator elements. Each element is separated by a dash.

Typical part number: VRAD-0x5x16-0.27-1.35-2x25-12.6-118x0.24-118x0.24-D-C

Part number element definitions:

VRAD (Versatile Rotary Actuator Device series)

Width x Height x Depth (specified in tenths of an inch – leading 0 indicates round)

Torque Factor (specified in Millions of Dyne\*CM per Amp)

Magnetic Spring Stiffness (specified in Thousands of Dyne\*CM per mechanical degree)

Number of coils and resistance per coil (specified in ohms)

Inductance of all coils in series (specified in millihenry tested at 1kHz)

Front Shaft diameter and length (diameter specified thousandths, length in inches)

Rear shaft diameter and length (diameter specified thousandths, length in inches)

Bearing preload configuration (A=axial, D=radial, N=none, R=from rear, F=from front, # in pounds)

Temperature range (C = Commercial, I = Industrial)

Note that we can customize each of these elements for individual applications. Please contact us if you have special requirements not met by the standard actuator.

### MORE INFORMATION

More information about the Versatile Rotary Actuator, including additional application hints and tips can be found on the ScannerMAX web site at [www.ScannerMAX.com](http://www.ScannerMAX.com).

In addition, OEMs are strongly encouraged to work with us to make sure that the most appropriate actuator is chosen and designed-in.

### PATENT AND TRADEMARK INFORMATION

US and International Utility Patents Pending on the theory of operation and assembly techniques.

German Patent (Utility Model) Number: 20 2012 009 275.8

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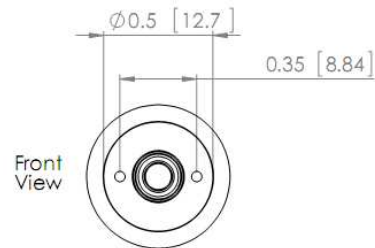
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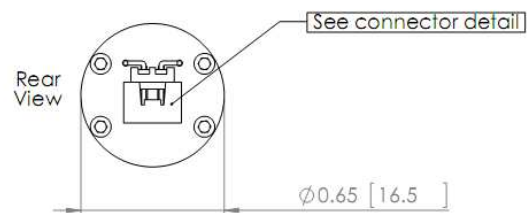
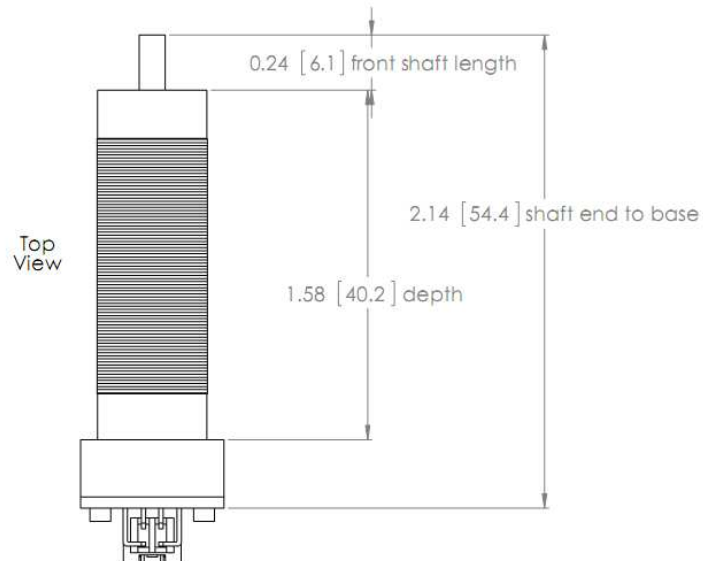
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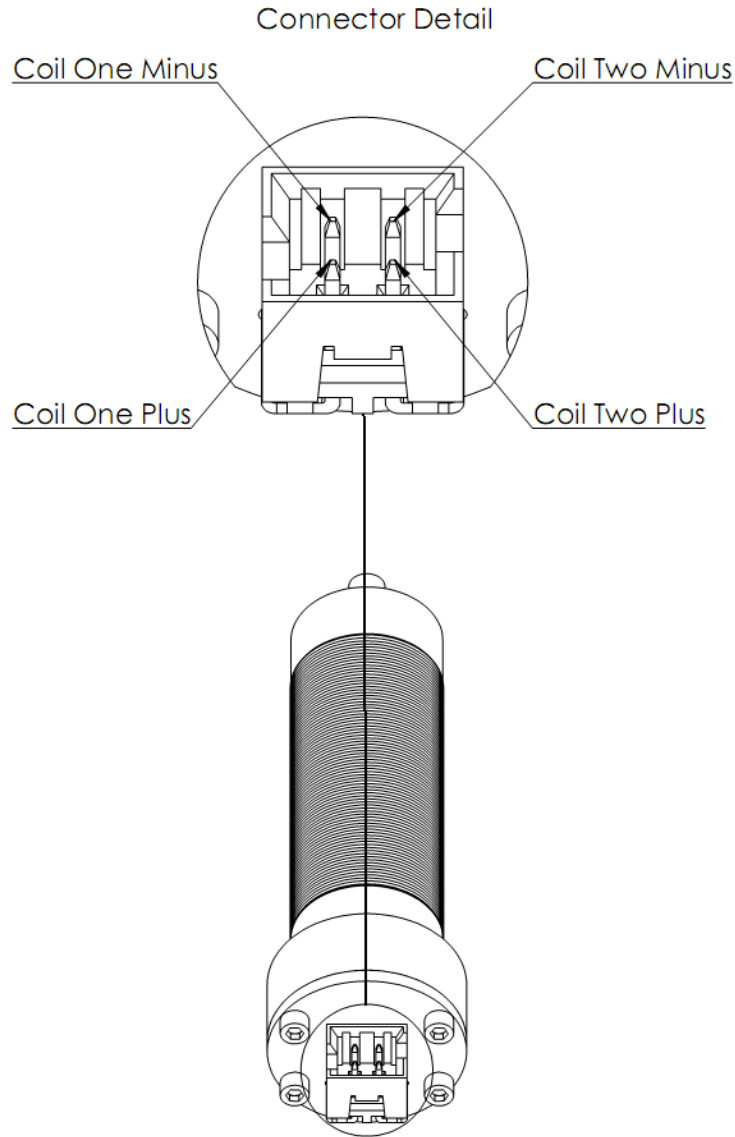
### PHYSICAL DIMENSIONS



Front screw holes: #0-80 thread  
Front shaft diameter: 0.118 [3.00]



DIMENSIONS ARE IN INCHES [millimeters]



Actuator mating connector is 4-pin Molex part number 51110-0460

Pin inserts are Molex part number 50394-8052

(Pins may be carefully crimped using pliers, or Molex Hand Crimp Tool Order Number 63819-0100)

We provide the mating connector and six pins, although only four are needed.

(We provide extras incase of oops...)



**Versatile Rotary Actuator Device**  
**VRAD 516 series**  
(patents pending)

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