CONTROLLING ANTENNAS POWERED BY AC OR LARGE DC MOTORS WITH THE RC1500 OR RC2000 ANTENNA CONTROLLERS

The RC1500A, RC2000A, and RC2000C antenna controllers are designed to control satellite antennas powered by 36 volt DC motors which use pulse type position sensors. The RC1500A is designed for use with single axis polar mount antennas. The maximum output current from the RC1500A is 5 amps. The RC1500A has a built-in interface for a Chaparral type polarotor. The RC2000A and RC2000C are dual axis antenna controllers designed for use with elevation over azimuth or azimuth over elevation type mounts as well as polar mounts with a motorized elevation (latitude angle) or motorized declination adjustment. The RC2000C has all of the features of the RC2000A as well as support for tracking inclined orbit satellites via step track and memory track algorithms. The RC2000A and RC2000C share a common motherboard. In the text that follows the term RC2000 will be used to refer to both versions. The maximum actuator drive current available from the RC2000 is 8 amps. The RC2000 has a built-in interface for a Chaparral type polarotor. There is an optional interface (designated RC2KPOL) for a 24 volt DC polarization motor which uses a potentiometer for feedback. With this option the output current available to the polarization motor is approximately 200 milliamps. This option was designed to be used with Seavey motorized feeds.

The two issues which must be addressed to successfully interface one of these controllers to a large antenna is the application of power to the antenna motors and sensing the antenna's position. This paper describes a technique to use the antenna controller's +/- 36 volt output voltage to activate AC and higher voltage DC motors as well as the selection and placement of pulse type position sensors which are compatible with these antenna controllers. This paper also includes a description of the products available from Research Concepts, Inc. (RCI) which implement the motor control scheme outlined in this paper and a sensor design example.

Controlling the Motors

Please refer to figure 1. The azimuth motor drive output of the RC2000 on the AZ1 and AZ2 terminals will be +/- 36 volts. When azimuth ccw movement is specified, AZ1 will have the higher voltage, and when azimuth cw movement is specified, AZ2 will have the higher voltage. (Note that the sense of antenna azimuth movement is as seen by an observer located above the antenna). In a similar fashion, when down movement is specified, EL1 will be at the higher voltage, and when upward movement is specified, EL2 will be at the higher potential. When azimuth ccw movement is specified, current will flow out of the AZ1 terminal of the RC2000, through the dropping RESISTOR, through STEERING DIODE D1, through the AZ CCW RELAY COIL, through the AZ CCW LIMIT SWITCH, through the AZ CW LIMIT SWITCH, and back into the AZ2 terminal of the RC2000. Current flowing through the AZ CCW RELAY COIL will activate the relay and close the AZ CCW CONTACT CLOSURE. This will configure the POWER CONTACTOR to move the antenna in the azimuth ccw direction. When azimuth ccw current flows STEERING DIODE D2 keeps current from flowing through the azimuth CW RELAY COIL.

When the antenna is within the azimuth CCW limit, the AZ CCW LIMIT SWITCH is closed. When the azimuth ccw limit is reached, the AZ CCW LIMIT SWITCH will open. When the AZ CCW LIMIT SWITCH is open, STEERING DIODE D3 will keep azimuth ccw current from flowing, but will allow azimuth cw current to flow to move the antenna out of the ccw limit. Azimuth cw movement is accomplished in a similar fashion. Note that limit switches are not required. The RC1500A and RC2000 maintain logical limits based on the position count. Limit switches are pretty cheap insurance, however.

The purpose of the dropping resistor is to match the output voltage of the RC1500A or RC2000 (36 volts) to the voltage necessary to activate the relay coils. A common relay coil voltage is 24 volts. If the relays have 24 volt coils, the dropping resistor should be selected so that at the relay's rated coil current the voltage drop across the resistor will be 12 volts. If 36 volt relays are used the dropping resistor is not needed.

A number of products are available from Research Concepts which implement the motor control scheme outline above. See the section below entitled Motor Control Interface Products for a description of these products.

Note that the scheme shown in Figure 1 does not support slow speed movement. With 36 volt motors, the RC1500 and RC2000 vary the motor speed by rapidly switching the 36 volt antenna drive signals off and on - which gives an average voltage of less than 36 volts. If this signal is applied to the circuit of Figure 1, the relays would chatter. On the RC2000, slow speed movement may be disabled by setting the azimuth and elevation slow speed codes to 254. On the RC1500, slow speed movement is disabled by setting the slow speed index to the highest possible value.

When controlling AC or large DC motors with either the RC1500 or RC2000, it may be necessary to change the controller's ANTI-REVERSAL DEADBAND, COAST, RETRY COUNT, and MAXIMUM POSITION ERROR parameters. These parameters control the movement of the antenna.

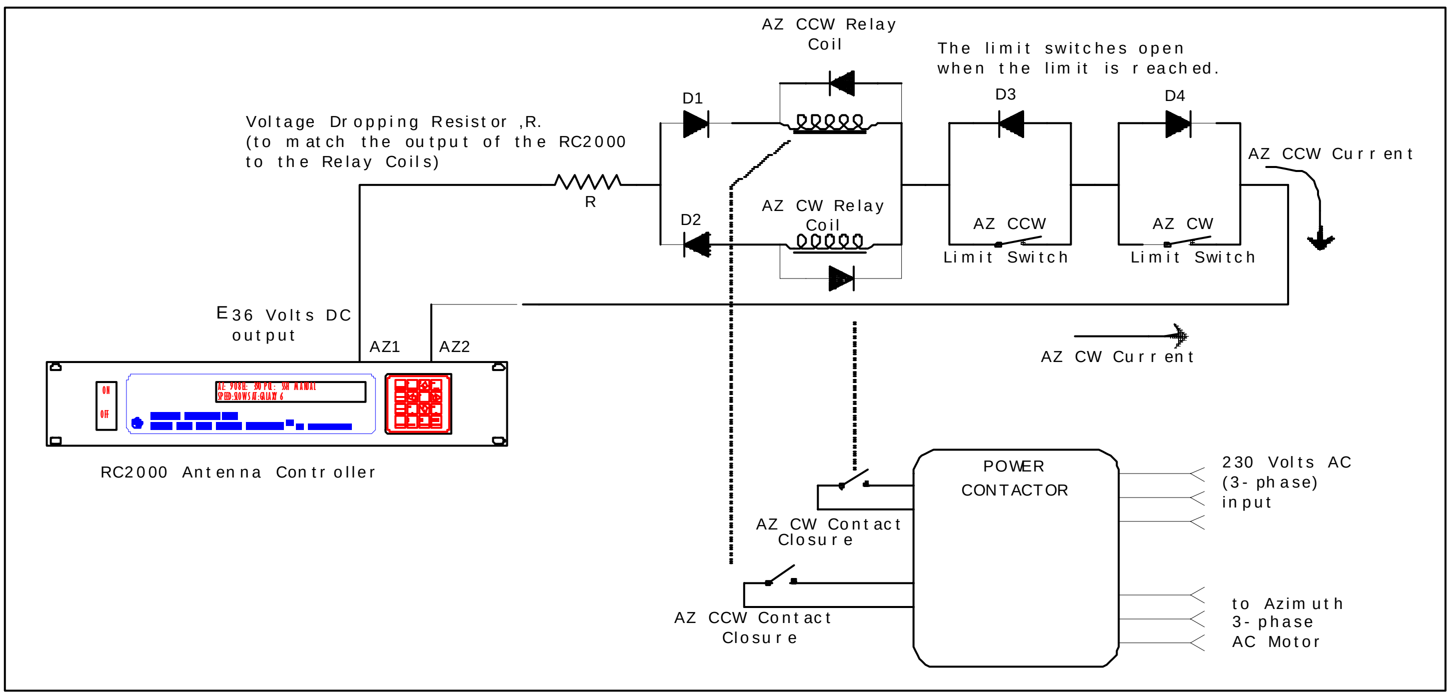


Figure 1.

When the antenna has been moving in one direction, it must be allowed to come to a complete stop before it is commanded to move in the opposite direction, or position pulses may not be accumulated properly. The ANTI-REVERSAL DEADBAND specifies the minimum number of milliseconds between antenna movements in opposite directions. On the RC2000A the user may specify four deadbands, azimuth fast, azimuth slow, elevation fast, and elevation slow. For the RC2000C the user can specify two deadbands - az/el fast and az/el slow. When the circuit of Figure 1 is used, the fast and slow deadbands for a given axis should be set to the same value.

When the antenna is performing an automatic move to a target position, the antenna drive signals are released before the antenna reaches the target position. The idea is that the drive signals are released and the antenna coasts into position. The COAST parameters specify the number of position counts before a target position is reached where the drive signals are released. There are unique COAST parameters for each axis on the RC2000.

When the antenna is performing an automatic move, the controller will make a number of attempts to hit the target position. The RETRY COUNT parameter specifies how many attempts the controller will make to reach the target position. The MAXIMUM POSITION ERROR parameter specifies the maximum allowable error about the target position. If the antenna comes to a stop within maximum position error counts of the target position, the controller will not attempt to make another move to get the antenna closer to the target position.

On the RC2000 these parameters may be set by the user via CONFIG mode. On the RC1500 these parameters are programmed into the controller's EPROM memory and can only be changed at the factory.

Polarization Control

If the polarization is controlled with something other than a polarotor, an interface for a polarization motor is necessary. If control for a polarization motor is needed, use the RC2000 with the RC2KPOL option. For a single axis antenna this will mean that the elevation control capability of the RC2000 is not used. The polarization control can use a scheme similar to that used for the azimuth and elevation axis which employs relays and steering diodes. Note that the RC2KPOL option requires the use of a potentiometer for position sensing.

Motor Control Interface Products

A number of products are available from RCI which implement the motor control scheme outlined above.

The 2K90INT is a board level product which implements azimuth, elevation, and polarization control circuits based on the method outlined in figure 1 above. The contact closures generated by the 2K90INT board are isolated from the antenna controller’s control outputs and can be used to activate either contactors which control three phase AC motors or DC motors. When used with DC motor drive modules, the 2K90INT board supports a latching relay which allows a single DC motor drive module to power both the azimuth and elevation motors (not simultaneously). This allows for a lower cost installation.

The RC2K90INT-1 and RC2K90INT-2 interface boxes use the 2K90INT circuit board described above with a KBPB DC motor drive module manufactured by KB Electronics (ph: 954 346 4900) to power either 90 or 180 volt DC azimuth and elevation motors. The interface boxes are housed in NEMA 4 enclosures suitable for outdoor mounting. The RC2K90INT-1 interface box uses the latching relay feature described in the previous paragraph to allow a single KBPB DC motor drive module to control both the azimuth and elevation axis. With the RC2K90INT-1 simultaneous azimuth and elevation movement is not supported. The RC2K90INT-2 uses a pair of KBPB motor drive modules and supports simultaneous azimuth and elevation movement. With both interface boxes, the only support for polarization movement is a pair form C relay contact closures activated by steering diodes. These outputs can be used with a DC power supply to control a rotating feed powered by a DC motor if the drive output of the RC2KPOL daughterboard is not suitable for direct interface with the polarization motor.

A heater option is available for the RC2K90INT-1 and RC2K90INT-2 interface boxes that allows operation at temperatures to -45 C.

Position Sensor Interface

The RC1500A and RC2000 antenna controllers require the use of single phase pulse type sensors to determine the position of the antenna. A pulse type sensor produces a rectangular shaped waveform as the antenna moves about the axis associated with the sensor. A quadrature pulse type sensor produces 2 rectangular waveforms, one being 90 degrees out of phase with the other. With a quadrature type pulse sensor it is possible to determine which way the antenna is moving. The RC1500A and RC2000 antenna controllers are not compatible with quadrature pulse sensors. Please see figure 2.

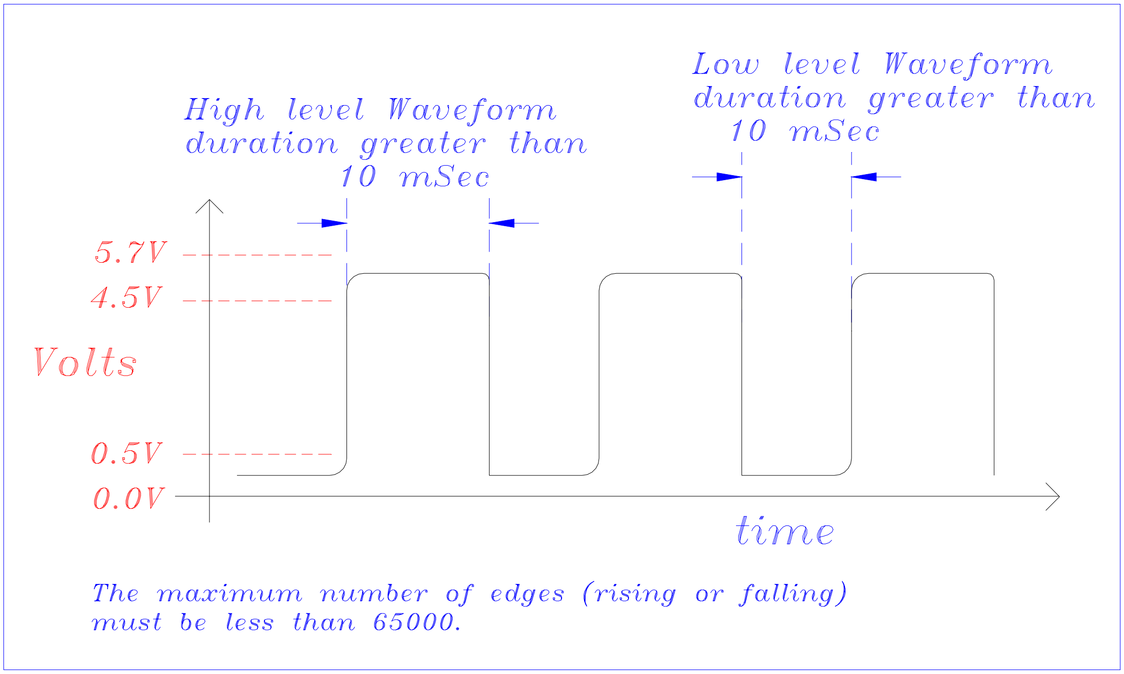


Figure 2.

The RC1500A and RC2000 antenna controllers count the number of rising and falling edges of the waveform. The position count is decremented for azimuth ccw movement and incremented for azimuth cw movement. The waveform's high level should be 4.5 to 5.7 volts, and the low level should be 0.0 to 0.5 volts. The waveform's minimum high or low pulse duration should be at least 10 milliseconds. This means that pulses less than 10 milliseconds long may not be detected by the antenna controller. The maximum number of counts from the antenna's azimuth ccw limit to its azimuth cw limit should be less than 65000. Remember, each rising edge and each falling edge of the sensor's output waveform is a separate count.

Many large antennas use a sensor attached directly to each of the fundamental axis of the antenna. The sensor used may be a resolver, synchro, potentiometer, or a quadrature pulse encoder. A pulse type sensor attached to the fundamental axis of the antenna is not suitable for use with the RC1500A or RC2000 antenna controllers. The reason for this requires a bit of explanation.

When a rising or falling edge is detected on the antenna controller's sensor input, the antenna controller must determine whether to increment or decrement the position count. Since single phase pulse sensors are used, the antenna controller must determine which way the antenna was last commanded to move, and decrement or increment the count accordingly. With a pulse sensor connected directly to the antenna's fundamental axis, when the antenna vibrates back and forth due to wind, the pulse sensor produces a steady stream of pulses. The antenna controller will increment or decrement the count depending on which way the antenna was last commanded to move. In reality the antenna is just vibrating in the wind and not really moving. The result of this is an error in the position count maintained by the antenna controller.

The antenna controllers are designed to work with 36 volt actuators. With these actuators the pulse sensor is connected directly to the motor. The motor typically drives either a worm or screw type gear, which will not allow forces applied to the antenna to cause rotation of the motor. Therefore, no false counts are recorded by the antenna controller.

On a large antenna, the solution to the sensor dilemma is to place a sensor on the output of the motor. Most motors attach to either gear reduction systems or linear actuators via a C56 type flange. There are pulse sensors which may be placed between the motor and the transmission at this flange. Remember that any pulse sensor used must conform to the requirements of the antenna controller, which are: 1) the total number of rising and falling edges must not exceed 65000, 2) the duration of the high and low segments of the waveform must be at least 10 milliseconds, 3) the high level of the waveform must be 4.5 to 5.7 volts, 4) the low level of the waveform must be 0.0 to 0.5 volts, and 5) sensor must be a zero speed type which will count rotation of the motor shaft at very low speed. Inductive pickup type sensors do not generally meet the last requirement.

A number of manufacturers make sensors which may be placed directly between the motor and the gear reducer of the sensor on the C56 flange. Powermation's #DTK056M1 (ph. 800 811 2691, www.powermation.com) and Dart's CF Series (ph. 317-873-5211, www.dartcontrols.com) are two examples. RCI resells the Powermation products. These sensors consist of a Hall effect pickup and a magnet wheel which attaches to the shaft of the motor via set screws. They are available with several different pulse per revolution characteristics. In most cases, a pulse sensor with a one pulse per revolution characteristic is appropriate. Both of these sensors increase the separation between the motor and the gear reducer or actuator by 0.750". In many cases the existing shaft coupling mechanism can accommodate this extra separation without modification.

Regardless of what types of sensors are used, the user must ensure that the five requirements outlined above for the sensor waveform are met. Some signal conditioning circuits may be required to meet the waveform high and low level specification. Note that there is a 5.7 volt supply available on the back of the antenna controller which is meant to be used with the polarotor. The maximum current draw from this supply should not exceed 200 milliamps. Also note that shielded cables are required to interface the antenna controller to the pulse sensors - see the antenna controller manual for more information. Appropriate cables are available from RCI.

To insure that the pulse duration requirement is not violated, the user should consider the speed of the motor and the number of pulses produced by the sensor for each revolution of the motor. To determine the number of pulses per second, take the motor speed in revolutions per minute (rpm) and divide by 60 to get revolutions per second. Multiply this value by the number of pulses per revolution to obtain the number of pulses per second. To obtain the pulse duration in milliseconds, divide 500 by the number of pulses per second. Mathematically, this formula is...

PULSE_DURATION (milliseconds) = 30000 / (RPM x PULSES_PER REVOLUTION)

Here is an example:

Motor Speed: 1750 rpm

Pulse Sensor: 1 pulse per revolution

Pulse Duration = 30000 / (1750 x 1) = 17.14 milliseconds

To make sure that the total sensor waveform edge count requirement is satisfied, the user must determine how many revolutions of the motor are required to move from the azimuth ccw limit to the azimuth cw limit (and from the down to the up limit) along with how many edges are produced for each revolution of the motor.

With the Powermation and Dart pulse sensors mentioned above, the user can select from the following the number of pulses per revolution: 1, 2, 15, or 60. The question comes up - how many pulses per revolution are required? The number of pulses per revolution of the motor determines the resolution with which the antenna controller can position the antenna. In general, it is sufficient to have 10 position counts over the antenna's 3 dB beamwidth. Remember that the controller counts both the rising and falling edges of each position pulse.

See the section of this paper entitled Pulse Sensor Selection Design Example which gives a step by step design example for a 6.1 meter Ku band antenna.

Pulse Sensor Selection Design Example

Here is a design example for the azimuth axis of a 6.1 meter antenna (the calculation for the elevation axis is similar)...

Antenna Size: 6.1 meters

Operating Frequency: Ku Band (12 GHz)

Azimuth Motor RPM: 1750

Range of antenna azimuth movement: 100 degrees

From this information the 3 dB beamwidth of the antenna can be determined to be: 0.28 degrees

To determine the total number motor revolutions which occur when moving from the antenna's azimuth ccw limit to the antenna's cw limit and to get a rough idea of the number motor revolutions per each degree of movement determine the time that it takes for the antenna to move through a known angle.

For this case determine the time that it takes the antenna to move from limit to limit (100 degrees for this example): use 110 seconds for this example

Determine the total number of motor revolutions per second: 1750 rpm / 60 seconds = 29.16 revolutions per second.

Determine the number of motor revolutions required to move from limit to limit: 29.16 revolutions per second x 110 seconds = 3208 motor revolutions.

Choose a Powermation pulse sensor with a one pulse per revolution characteristic and check to make sure that the requirements outlined earlier are satisfied:

- The duration of the pulse high and low level waveforms is greater than 10 milliseconds,
- The total number of position counts encountered moving from limit to limit is less than 65000, and
- There are at least 10 position counts which occur as the antenna is moved across its 3 dB beamwidth.

Make sure that the total number of position counts when moving from limit to limit is less than 65000. This is easy. If there are 3208 motor revolutions, one pulse per revolution, and given the fact that the controller counts both the rising and falling edge of each position pulse the total number of position counts can be calculated to be:

3208 motor revolutions x 1 pulse per revolution x 2 edges per pulse = 6416 total position counts

This easily satisfies the requirement that there be less than 65000 total position counts.

Next make sure that the pulse waveform high and low duration is greater than 10 milliseconds. Use the formula given above: 30000 / (1750 RPM x 1 PULSE PER REVOLUTION) = 17.14 milliseconds per pulse. This satisfies the requirement that the pulse duration be greater than 10 milliseconds.

Next calculate the number of position counts which occur as the antenna moves over a 3 dB beamwidth. If there are 6416 position counts over 100 degrees, the number of position counts per degree is 6416 divided by 100 or 64.16 counts per degree. To calculate the number of position counts which occur as the antenna moves over its 3 dB beamwidth (0.28 degrees), multiply the 64.16 counts per degree by 0.28 degrees to obtain 17.96 position counts. This satisfies the requirement that there be at least 10 position counts over the antenna's 3 dB beamwidth.

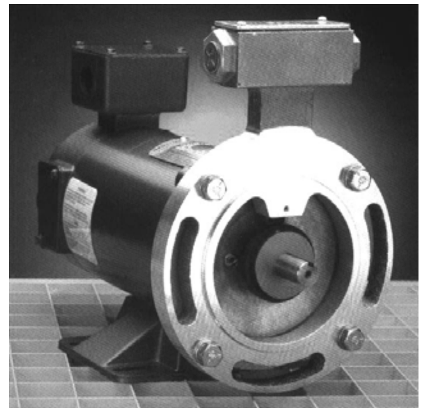
For more information please contact Research Concepts, Inc., 5420 Martindale, Shawnee, KS 66218-9680, USA, phone: (913) 422-0210, fax: (913) 422-0211, email: support@researchconcepts.com, web site: www.researchconcepts.com

Revision History

June 23, 2005 – source document BIGMOTOR_020901-mds.doc, modify info on powermation sensors, revise powermation cutsheet and append to this document.
SMM

DIGITAL TACHOMETER SENSOR KITS

Research Concepts, Inc. 5420 Martindale, Shawnee, KS 66218 913-422-0210
Fax: 913-422-0211   www.researchconcepts.com   sales@researchconcepts.com



SPECIFICATIONS

INPUT: 5-16 VDC
OUTPUT: NPN, 20ma
TEMPERATURE: Minus 40^{0}C to 120^{0}C
OUTPUT CONNECTION: Three Wire
PULSES PER REVOLUTION (ppr): 1
(2, 15 & 60 ppr models are available)
WAVE FORM: Square Wave
ENVIRONMENT: Impervious to dust, oil & water
MANUFACTUER: Powermation

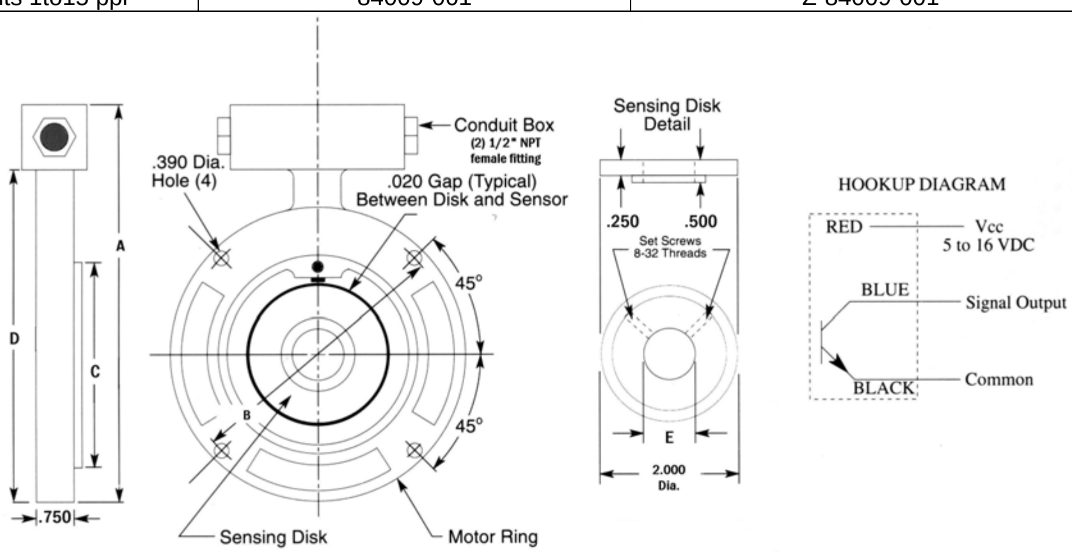
ORDERING CHART

MOTOR FRAME SIZE	POWERMATION NUMBER	RCI PART NUMBER	DIMENSIONS A	B	C	D	E
56C	DTK-056 M1	Z-DTK-056M1	9.375	5.875	4.500	7.875	5/8”
143TC, 145TC, 182C & 184C	DTK-184 M1	Z-DTK-184M1	9.375	5.875	4.500	7.875	7/8”
182TC, 184TC, 213C, 215C &254C	DTK-215 M1	Z-DTK-215 M1	12.312	7.250	8.500	10.000	1-1/8”
213TC, 215TC, 254UC & 256UC	DTK-254 M1	Z-DTK-254 M1	12.312	7.250	8.500	10.000	1-3/8”
254TC & 256TC	DTK-256 M1	-	12.312	7.250	8.500	10.000	1-5/8”

NOTE: Kits consist of motor face ring, sensor, mounting bolts and sensing wheel.

REPLACEMENT MAGNET WHEELS	POWERMATION PART NUMBER	RCI PART NUMBER
Model DTK-056 M1 5/8” Dia. shaft	RM2-1-.625	Z-RM2-1-_625
Model DTK-184 M1 7/8” Dia. shaft	RM2-1-0.875	Z-RM2-1_875
Model DTK-215 M1 1.125 Dia. shaft	RMR-1-1.125	Z-RM2-1_125

REPLACEMENT HALL EFFECT SENSOR ELEMENT	POWERMATION PART NUMBER	RCI PART NUMBER
For all sensor kits 1to15 ppr	84009-001	Z-84009-001



NOTE: To interface sensor to controller, use a shielded triple (18-22 AWG) with bare drain wire, such as Belden 8772.