



Rotary Motion Servo Plant: SRV02

SRV02



User Manual

Table of Contents

1. PRESENTATION.....	1
1.1. Description.....	1
1.2. SRV02 Options.....	1
2. MODULE OPTIONS AND EXPERIMENT OVERVIEW.....	2
3. SRV02 COMPONENTS.....	4
3.1. SRV02 Component Nomenclature.....	4
3.2. Component Description.....	6
3.2.1. DC Motor (Component #9).....	6
3.2.2. Potentiometer (Component #11).....	7
3.2.3. Tachometer (Component #13).....	7
3.2.4. Encoder (Component #12).....	8
3.3. SRV02-ETS Components.....	9
3.3.1. Slip Ring Description.....	10
4. SRV02 SPECIFICATIONS.....	10
5. SYSTEM CONFIGURATION AND SETUP.....	12
5.1. Gear Configuration.....	12
5.1.1. Description.....	12
5.1.2. Changing Gear Configuration.....	13
5.2. Load Configuration.....	13
5.2.1. Description.....	13
5.2.2. Installing Load.....	14
6. WIRING PROCEDURE.....	14

6.1. Cable Nomenclature.....15

6.2. Typical Connections using UPM.....16

6.3. Typical Connections with the Q3.....19

7. TESTING AND TROUBLESHOOTING.....21

7.1. Motor.....21

 7.1.1. Testing.....21

 7.1.2. Troubleshooting.....21

7.2. Testing the Potentiometer.....22

 7.2.1. Testing.....22

 7.2.2. Troubleshooting.....22

7.3. Tachometer.....22

 7.3.1. Testing.....22

 7.3.2. Troubleshooting.....22

7.4. Encoder.....23

 7.4.1. Testing.....23

 7.4.2. Troubleshooting.....23

8. TECHNICAL SUPPORT.....23

9. REFERENCES.....24

APPENDIX A: MOTOR SPECIFICATION SHEET.....25

APPENDIX B: TACHOMETER SPECIFICATION SHEET.....26

APPENDIX C: POTENTIOMETER SPECIFICATION SHEET.....27

APPENDIX D: ENCODER SPECIFICATION SHEET.....28

1. Presentation

1.1. Description

The Quanser SRV02 rotary servo plant, pictured in Figure 1, consists of a DC motor that is encased in a solid aluminum frame and equipped with a planetary gearbox. That is, the motor has its own internal gearbox that drives external gears. The basic SRV02 units comes with an potentiometer sensor that can be used to measure angular position of the load gear. The SRV02 device can also be fitted with an encoder to obtain a digital position measurement and a tachometer to measure the speed of the load gear.



Figure 1: SRV02 system.

1.2. SRV02 Options

As summarized in Table 1, there are six different SRV02 options available. In any of the options, SRV02 always includes the motor/gearbox actuator and a potentiometer. The different SRV02 options feature additional sensors, such as a tachometer in the SRV02-T system or an encoder in the SRV02-E model. The different options enable users to work with both analog and digital position measurements as well as measuring the angular rate using a tachometer.

<i>SRV02 Option</i>	<i>Sensor</i>
SRV02	Potentiometer
SRV02-E	Potentiometer Encoder (1024 line)
SRV02-EHR	Potentiometer High-resolution encoder (2042 line)
SRV02-T	Potentiometer Tachometer.
SRV02-ET	Potentiometer Encoder (1024 line) Tachometer.
SRV02-ETS	Potentiometer Encoder (1024 line) Tachometer. Slipping

Table 1: Summary of SRV02 Options

2. Module Options and Experiment Overview

The SRV02 rotary plant can be used stand-alone for several experiments but it also serve as a base component for several add-on modules. Table 2 below lists these modules and the corresponding experiments that are supplied with them. Thus a new plant is obtained by adding a module which presents new modeling and control challenges.

<i>Module Name</i>	<i>Experiment #</i>	<i>Experiment Name</i>	<i>Description</i>
N/A	0	SRV02 Quarc Integration	Describes how to use Quarc to drive the SRV02 motor and read its sensors.
N/A	1	Modeling	Model the speed of the SRV02 using a first-order transfer function.
N/A	2	Position Control	Regulate position of the SRV02 load gear to a desired angle using PID.
N/A	3	Speed Control	Control the angular rate of the SRV02 load gears using a PI and a lead compensator.
Ball and beam	4	Balance Control	Model the system and develop a cascade PD controller to stabilize the ball to a position along the beam.

<i>Module Name</i>	<i>Experiment #</i>	<i>Experiment Name</i>	<i>Description</i>
Flexible Joint	5	Vibration Control	Derive the plant dynamics and design a controller that compensates for the flexibilities in the joint while regulating the position of the arm tip to desired location.
Flexible Link	6	Vibration Control	Model the plant and identify the natural frequency of the beam. Then, develop a system that controls the tip of beam to a desired position.
Single Pendulum	7	Gantry Control	Obtain the dynamics of the rotary pendulum system and control the tip of the pendulum to a set angular position.
Single Pendulum	8	Self-Erecting Single Inverted Pendulum Control	Design a nonlinear energy-based swing-up controller and a linear balance compensator to swing-up the pendulum from the resting downward position to the upright vertical position.
Double Pendulum	9	Double-Inverted Pendulum Balance Control	Model the system and then design a controller that balances the pendulum while the servo is tracking a reference position.
Gyroscope	10	Heading Control	Design a feedback loop that can maintains the position of the SRV02 load gear, i.e. the heading, while the rotary base underneath is manually perturbed.
1-DOF Torsion	11	Vibration Control	Control the position of the output shaft to desired setpoint by rejecting the vibrations introduced by the torsional member.
2-DOF Torsion	12	Vibration Control	Control the position of the output shaft to desired setpoint by rejecting the vibrations introduced by both torsional members.
2-DOF Robot	13	2D Task-Based Position Control	Control the position of the end-effector given a desired planar (x,y) position. This involves servo position control as well as developing the forward and inverse kinematics of the plant.
2-DOF Pendulum	14	2-DOF Gantry Control	Control the position of the pendulum tip to a desired (x,y) position while dampening the motions of the pendulum.
2-DOF Pendulum	15	2-DOF Inverted Pendulum Balance Control	Develop a balance controller that keeps the 2-DOF pendulum in the upright vertical position.

<i>Module Name</i>	<i>Experiment #</i>	<i>Experiment Name</i>	<i>Description</i>
Solar Tracker	16	Various	Transfer function parameters are found using frequency response and the obtained model is used to design a servo position control. The light sensor characteristics are identified and then used to perform light tracking.
2D Ball Balancer	17	Position Control	Control the position of a ball that is free to move on a swiveling 2-DOF plate. The plate angles are controlled by attached servo units and the ball position is measured using an overhead digital camera with image processing software.

Table 2: Modules in the rotary family package.

3. SRV02 Components

The SRV02 components are identified in Section 3.1. Some of the those components are then described in Section 3.2.

3.1. SRV02 Component Nomenclature

The SRV02 components listed in Table 3 below are labeled in figures 2, 3, 4, 5, and 6. Note that Figure 2 shows the SRV02 in the low-gear configuration and Figure 6 is the SRV02 in the high-gear configuration. These different gear setups will be explained later in Section 5.1.

<i>ID #</i>	<i>Component</i>	<i>ID #</i>	<i>Component</i>
1	Top plate	13	Tachometer
2	Bottom plate	14	Ball-bearing block
3	Posts	15	Motor connector
4	Motor pinion gear: 72-teeth (low-gear)	16	Tachometer connector
5	Load gear: 72-teeth (low-gear)	17	Encoder connector
6	Potentiometer anti-backlash gear	18	S1 & S2 connector (i.e. potentiometer)
7	Anti-backlash springs	19	Motor pinion gear: 24-teeth (high-gear)
8	Load shaft (i.e. output shaft)	20	Load gear: 120-teeth (high-gear)
9	Motor	21	Bar inertial load.
10	Gearbox	22	Disc inertial load.

<i>ID #</i>	<i>Component</i>	<i>ID #</i>	<i>Component</i>
11	Potentiometer	23	Thumb screws.
12	Encoder		

Table 3: SRV02 components.



Figure 2: Top view of components on the SRV02 in low-gear configuration.

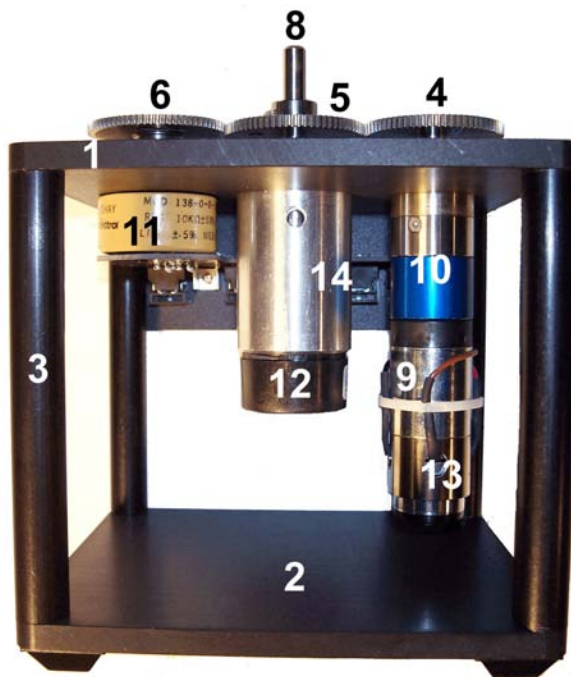


Figure 3: Front view of the SRV02 components.

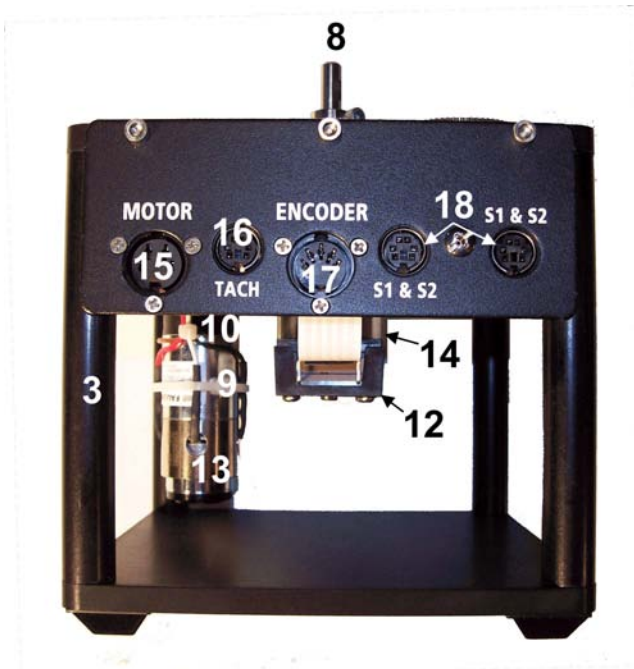


Figure 4: Connectors view of the SRV02.



Figure 5: Top view of the components on the SRV02 in high-gear configuration.

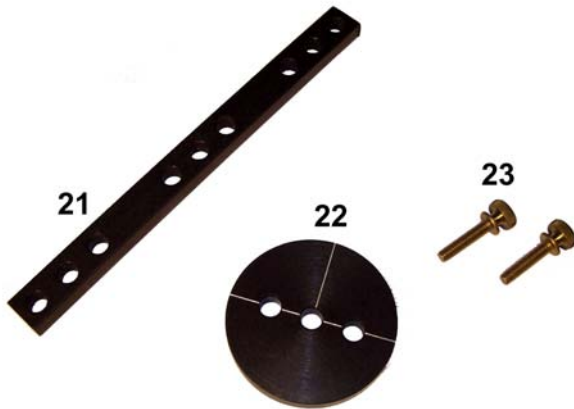


Figure 6: Inertial loads supplied with SRV02 system.

3.2. Component Description

3.2.1. DC Motor (Component #9)

The SRV02 incorporates a Faulhaber Coreless DC Motor model 2338S006 and is shown in Figure 3 with ID #9. This is a high efficiency, low inductance motor with a small rotor inductance. Therefore it can obtain a much faster response than a conventional DC motor. The complete specification sheet of the motor is included in Appendix A.

CAUTION: High frequency signals applied to a motor will eventually damage the gearbox and/or the motor brushes. The most likely source for high frequency noise is derivative feedback. If the derivative gain is set too high, a noisy voltage will be fed into the motor. To protect your motor, you should always band limit your signal (especially derivative feedback) to a value of 50Hz.

CAUTION: Input: $\pm 15\text{V}$, 3A peak, 1A continuous.

CAUTION: Exposed moving parts.

3.2.2. Potentiometer (Component #11)

All SRV02 models are equipped with a Vishay Spectrol model 132 potentiometer, shown in Figure 3 with label #11. It is a single turn 10 k Ω sensor with no physical stops and has an electrical range of 352 degrees. The total output range of the sensor is $\pm 5\text{ V}$ over the full 352 degree range. Note that a potentiometer provides an absolute position measurement as opposed to a relative measurement from, for instance, an incremental encoder. See Appendix C for a full listing of the potentiometer specifications.

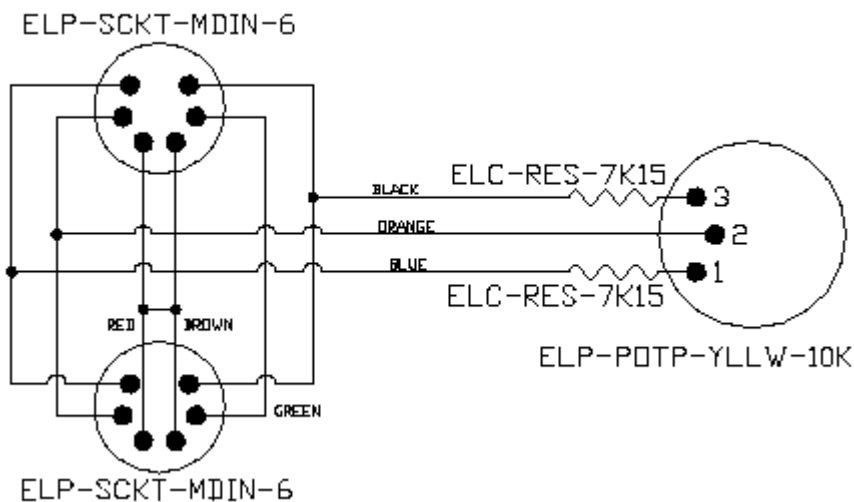


Figure 7: SRV02 potentiometer wiring.

As illustrated in Figure 7, the potentiometer is connected to a $\pm 12\text{ V}$ DC power supply through two 7.15 k Ω bias resistors. Under normal operations, terminal 1 should measure -5 V while terminal 3 should measure $+5\text{ V}$. The actual position signal is available at terminal 2.

3.2.3. Tachometer (Component #13)

The SRV02-T and SRV02-ET models come equipped with a tachometer that is directly attached to the DC motor and is depicted with ID #13 in Figure 3. This prevents any latencies in the timing of the

response and ensures that the speed of the motor is accurately measured. Refer to Appendix B for the tachometer specification sheet.

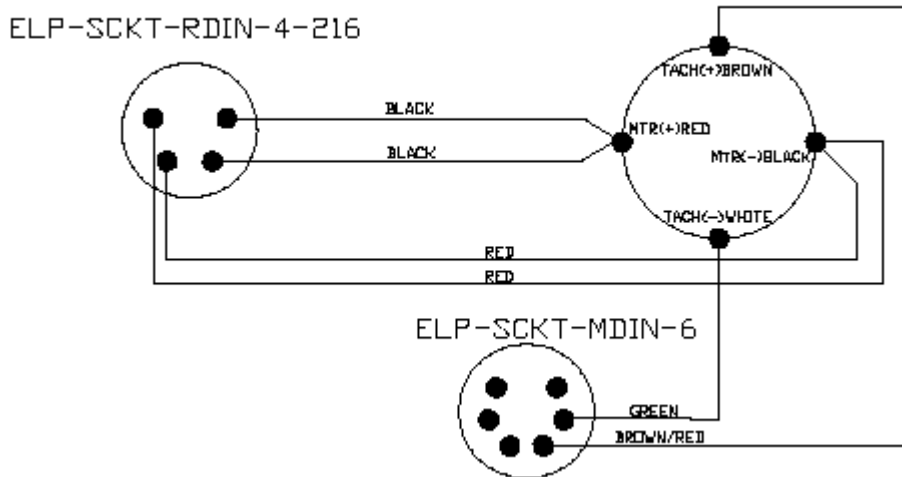


Figure 8: SRV02 Tachometer wiring.

The motor and tachometer wiring diagram is shown in Figure 8. The 4-pin DIN motor connector, component #19, connects the power amplifier to the positive and negative motor leads. This is the motor input voltage signal that drives the motor. The 6-pin mini DIN tachometer connector, component #18 in , is directly wired to the positive and negative tachometer terminals. This supplies a voltage signal that is proportional to the rotational speed. The tachometer connector is typically connected to the S3 analog input connector on the Universal Power Module.

3.2.4. Encoder (Component #12)

The SRV02-E and SRV02-EHR options have an optical encoder installed that measures the angular position of the load shaft. It is pictured in Figure 3 with the label #12. In the SRV02-E system, the encoder used is a US Digital S1 single-ended optical shaft encoder that offers a high resolution of 4096 counts per revolution in quadrature mode (1024 lines per revolution). The complete specification sheet of the S1 optical shaft encoder is given in Appendix D.

The encoder in the SRV02-EHR system has a resolution of 8192 counts per revolution in quadrature mode (2042 lines per revolution). Remark that incremental encoders measure the relative angle of the shaft (as opposed to the potentiometer which measures the absolute angle).

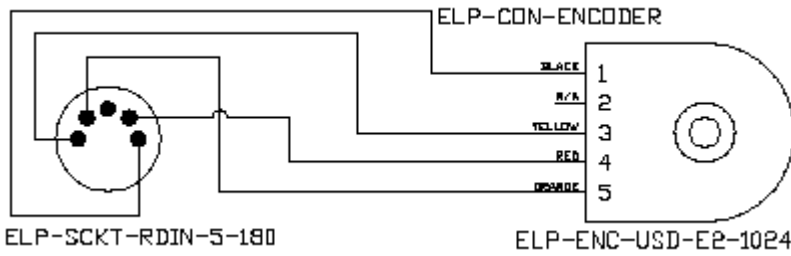


Figure 9: SRV02 encoder wiring.

The position signal generated by the encoder can be directly connected to the data-acquisition device using a standard 5-pin DIN cable. The internal wiring of the encoder and the 5-pin DIN connector on the SRV02, component #17, is illustrated in Figure 9.



CAUTION: Never connect the encoder to the Quanser Universal Power Module.

3.3. SRV02-ETS Components

The SRV02-ETS, pictured in Figure 10, is an SRV02-ET system with a slip ring mounted on the load gear. This allows an external load attached on top of the slip ring unit to rotate 360 degrees freely without any cable entanglements. In addition to the components listed in Table 3, Table 4 lists some components found on the SRV02-ETS unit alone.



Figure 10: SRV02-ETS.

The components in Table 4 are shown and identified in Figure 11.

<i>ID #</i>	<i>Component</i>	<i>ID #</i>	<i>Component</i>
24	Slip ring module chassis	28	Right connector on slip ring
25	Slip ring	29	Left connector on SRV02
26	Slip ring top plate	30	Right connector on SRV02
27	Left connector on slip ring		

Table 4: Additional components on the SRV02-ETS.



Figure 11: Components on the SRV02-ETS.

3.3.1. Slip Ring Description

The eight-contact slip ring channels the signals attached to the *Left* and *Right* connectors on the slip ring, ID #27 and ID #28 depicted in Figure 11, to the *Left* and *Right* connectors on the SRV02 base, ID #27 and ID #28 shown in Figure 11. This allows the load attached to the load gear atop the slip ring, ID #8, to move freely 360 degrees without any cable entanglements. This is especially useful, for instance, when used with the inverted rotary pendulum experiments.

4. SRV02 Specifications

Table 5, below, lists and characterizes the main parameters associated with the SRV02. Some of these are used in the mathematical model.

<i>Symbol</i>	<i>Description</i>	<i>Matlab Variable</i>	<i>Value</i>	<i>Unit</i>	<i>Variation</i>
V_{nom}	Motor nominal input voltage.		6.0	V	
R_m	Motor armature resistance.	Rm	2.6	Ω	$\pm 12\%$
L_m	Motor armature inductance.	Lm	0.18	mH	
k_t	Motor torque constant	k_t	7.68E-03	N·m	$\pm 12\%$
η_m	Motor efficiency.	Eff_M	0.69		$\pm 5\%$
k_m	Back-emf constant	k_m	7.68E-03	V/(rad/s)	$\pm 12\%$
$J_{m,rotor}$	Motor shaft moment of inertia.	Jm_rotor	3.90E-7	kg·m ²	$\pm 10\%$
K_{gi}	Internal gearbox ratio.	Kgi	14		
$K_{ge, low}$	External low-gear configuration ratio.	Kge	1		
$K_{ge, high}$	External high-gear configuration ratio.	Kge	5		
K_g	Low-gear Total gearbox ratio.	Kg	14		
	High-gear total gearbox ratio.		70		
η_g	Gearbox efficiency.	Eff_G	0.90		$\pm 10\%$
J_{tach}	Tachometer moment of inertia.	Jtach	7.06E-08	kg·m ²	$\pm 10\%$
m_{24}	Mass of 24-tooth gear.	m24	0.005	kg	
m_{72}	Mass of 72-tooth gear.	m72	0.030	kg	
m_{120}	Mass of 120-tooth gear.	m120	0.083	kg	
r_{24}	Radius of 24-tooth gear.	r24	6.35E-03	m	
r_{72}	Radius of 72-tooth gear.	r72	0.019	m	
r_{120}	Radius of 120-tooth gear.	r120	0.032	m	
J_{eq}	Equivalent high-gear moment of inertia without external load.	Jeq	9.76E-05	kg·m ²	$\pm 10\%$
	Equivalent high-gear moment of inertia without external load.	Jeq	2.08E-03	kg·m ²	$\pm 10\%$
B_{eq}	Low-gear viscous damping coefficient found experimentally.	Beq	1.50E-04	N·m/(rad/s)	$\pm 20\%$
	High-gear viscous damping coefficient found experimentally.	Beq	0.015	N·m/(rad/s)	$\pm 20\%$
m_b	Mass of bar load.	m_b	0.038	kg	
L_b	Length of bar load (from end-to-end).	L_b	0.1525	m	

<i>Symbol</i>	<i>Description</i>	<i>Matlab Variable</i>	<i>Value</i>	<i>Unit</i>	<i>Variation</i>
m_d	Mass of disc load.	<code>m_d</code>	0.04	kg	
r_d	Radius of disc load.	<code>r_d</code>	0.05	m	
K_{pot}	Potentiometer sensitivity	<code>K_POT</code>	35.2	deg/V	$\pm 2\%$
K_{enc}	SRV02-E encoder resolution.	<code>K_ENC</code>	4096	counts/rev	
K_{enc}	SRV02-EHR encoder resolution.	<code>K_ENC</code>	8192	counts/rev	
K_{tach}	SRV02-T tachometer sensitivity.	<code>K_TACH</code>	1.50	k_{RPM}/V	$\pm 2\%$
m_{max}	Maximum output shaft load.		5.0	kg	
f_{max}	Maximum input voltage frequency.		50.0	Hz	
I_{max}	Maximum input current		1.0	A	
ω_{max}	Maximum motor speed.		628.3	rad/s	

Table 5: SRV02 system specifications.

5. System Configuration and Setup

As discussed in Section 5.1, the SRV02 can be setup with two different gear configurations depending on the experiment being performed. Also, Section 5.2 shows how the SRV02 can be fitted with different loads.

5.1. Gear Configuration

5.1.1. Description

The SRV02 can be setup in the low-gear configuration or the high-gear configuration, as pictured in Figure 12 and Figure 13, respectively. The low-gear ratio is recommended when performing the modeling, position control, and speed control experiments with or without the bar and disc loads. The high-gear setup is required to be used with additional modules such as the ball-and-beam device, the flexible link module, and the gyroscope.



Figure 12: SRV02 in low-gear configuration.



Figure 13: SRV02 in high-gear configuration.

5.1.2. Changing Gear Configuration

Follow this procedure to change between high-gear and low-gear ratio:

1. Using the supplied Allen keys, loosen the set screws on the three gear shafts.
2. Remove the gears from the shafts.
3. Slide the new gears into place as described below:
 - Low-gear configuration shown in Figure 12: place the 72-tooth gear, ID#5 in Figure 2, onto the load shaft, ID #8 in Figure 2, and the 72-tooth pinion gear, ID#4 in Figure 2, on the motor shaft.
 - High-gear configuration depicted in Figure 13: slide the 120-tooth gear, ID#20 in Figure 5, followed by the 72-tooth gear, ID#8 in Figure 5, on the load shaft and place the 20-tooth pinion gear, ID #19 in Figure 5, on the motor shaft.

Note: The potentiometer gear, component #6 in Figure 5, is an anti-backlash gear and special precaution need to be taken when installing it. In order to insert it properly, rotate its two faces against each other such that the springs are partially pre-loaded. Do not fully extend the springs when you pre-load the gears.

4. Ensure the teeth of all the three gears are meshed together. Remark that in the high-gear setup, the top 72-tooth load gear is meshed with the potentiometer gear, ID #6 in Figure 5.
5. Tighten the set-screws on each shaft with the supplied Allen keys.

5.2. Load Configuration

5.2.1. Description

The SRV02 is supplied with two external loads: a bar and a disk. These can be attached to the SRV02 load gear to vary the moment of inertia seen at the output. The SRV02 with the end of the bar load

connected is pictured in Figure 14. Either the end of the bar or the center of the bar can be used. In Figure 15 the SRV02 with the disk load attached is shown.

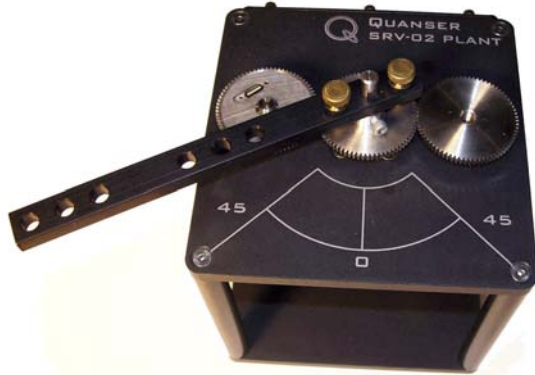


Figure 14: SRV02 with end of bar load attached .



Figure 15: SRV02 with disk load attached.

5.2.2. Installing Load

Follow this procedure to connect either the bar or disc load to the load gear:

1. Slide the center hole of the load on the output shaft of the SRV02, component # 8 in Figure 2. For the bar load (ID #21 in Figure 6), use either the center hole in the middle of the bar or the center hole at the an end of the bar onto the output shaft.
2. Align the two holes adjacent to the center hole with the screw holes of the load gear.
3. Using the two 8-32 thumb screws provided, ID #23 in Figure 6, fasten the inertial load to the output gear. The SRV02 with the bar load and the disk load attached is shown in Figure 14 and Figure 15, respectively. Make sure all the screws are properly tightened before operating the servo unit.



CAUTION: Do not apply a load greater than 5 kg at any time.

For instructions on how to install one the SRV02 modules (e.g. rotary flexible joint) see the user manual corresponding to that module.

6. Wiring Procedure

The following is a listing of the hardware components used in this experiment:

- **Power Amplifier:** Quanser UPM 1503/2405, or equivalent.
- **Data Acquisition Board:** Quanser Q8, Q4, Q3 ControlPaQ-FW, or equivalent.
- **Rotary Servo Plant:** Quanser SRV02, SRV02-T, SRV02- E, SRV02- EHR, SRV02-ET, or SRV02-ETS.

See the references listed in Section 9 for more information on these components. The cables supplied with the SRV02 are described in Section 6.1 and the procedure to connect the above components is

given in Section 6.2.

6.1. Cable Nomenclature

Table 6, below, provides a description of the standard cables used in the wiring of the SRV02 system.




<i>Cable</i>	<i>Designation</i>	<i>Description</i>
	5-pin-DIN to RCA	This cable connects an analog output of the data acquisition terminal board to the power module for proper power amplification.
	4-pin-DIN to 6-pin-DIN	This cable connects the output of the power module, after amplification, to the desired DC motor on the servo. One end of this cable contains a resistor that sets the amplification gain. For example when carrying a label showing "5" at both ends, the cable has that particular amplification gain. Typically a load cable gain of "1" is used for most SRV02 experiments.
	5-pin-stereo-DIN to 5-pin-stereo-DIN	This cable carries the encoder signals between an encoder connector and the data acquisition board (to the encoder counter). Namely, these signals are: +5VDC power supply, ground, channel A, and channel B.

Figure 16 "From Digital-To-Analog" Cable

Figure 17 "To Load" Cable Of Gain 1

Figure 18 "Encoder" Cable


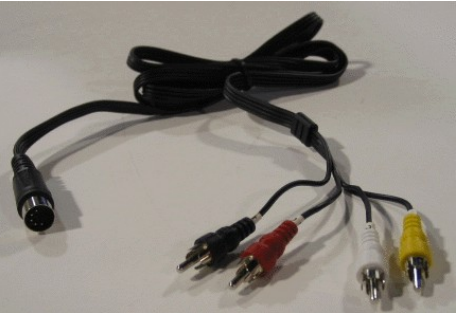
<i>Cable</i>	<i>Designation</i>	<i>Description</i>
 <p>Figure 19 "From Analog Sensors" Cable</p>	6-pin-mini-DIN to 6-pin-mini-DIN	This cable carries analog signals (e.g., from joystick, plant sensor) to the UPM, where the signals can be either monitored and/or used by a controller. The cable also carries a $\pm 12\text{VDC}$ line from the UPM in order to power a sensor and/or signal conditioning circuitry.
 <p>Figure 20 "To Analog-To-Digital" Cable</p>	5-pin-DIN to 4xRCA	This cable carries the analog signals, unchanged, from the UPM to the Digital-To-Analog input channels on the data acquisition terminal board.

Table 6 Cable Nomenclature

6.2. Typical Connections using UPM

This section describes the typical connections used for to connect the SRV02 plant to a data-acquisition board and a power amplifier. The connections are described in detail in the procedure below and summarized in Table 7.

Follow these steps to connect the SRV02 system:

1. It is assumed that the Quanser Q4 or Q8 board is already installed as discussed in the Reference [1]. If another data-acquisition device is being used, e.g. NI M-Series board, then go to its corresponding documentation and ensure it is properly installed.
2. Make sure everything is powered off before making any of these connections. This includes turning off your PC and the UPMs.
3. Connect the 5-pin-DIN to RCA cable from the *Analog Output Channel #0* on the terminal board to the *From D/A* Connector on the Quanser Universal Power Module, or UPM. See cable #1 shown in Figure 21 and Figure 22. This carries the attenuated motor voltage control signal, V_m/K_a , where K_a is the UPM amplifier gain.
4. Connect the 4-pin-stereo-DIN to 6-pin-stereo-DIN that is labeled **Gain 1** from *To Load* on the UPM to the *Motor* connector on the SRV02. See connection #2 shown in Figure 22 and Figure 23. This cable sets the gain of the amplifier to 1 and the connector on the UPM-side is black in colour. The cable transmits the amplified voltage that is applied to the SRV02 motor and is

denoted V_m .

5. If the SRV02 has the -E option then the encoder can be used to measure the load shaft angle. Connect the 5-pin-stereo-DIN to 5-pin-stereo-DIN cable from the *Encoder* connector on the SRV02 panel to *Encoder Input # 0* on the terminal board, as depicted by connection #3 in Figure 21 and Figure 23. This carries the load shaft angle measurement and is denoted by the variable θ_l .



CAUTION: Any encoder should be directly connected to the Quanser terminal board (or equivalent) using a standard 5-pin DIN cable. **DO NOT connect the encoder cable to the UPM!**

6. Connect the *To A/D* socket on the UPM to Analog Inputs #0-3 on the terminal board using the 5-pin-DIN to 4xRCA cable, as illustrated in Figure 21 and Figure 22. The RCA side of the cable is labeled with the channels. Note that the cable with label "1" is goes to Analog Input Channel #0.
7. Connect the *S1 & S2* connector on the SRV02 to the *S1 & S2* socket on the UPM using the 6-pin-mini-DIN to 6-pin-mini-DIN cable. See connection #5 in Figure 22 and Figure 23. This carries the voltage signal from the potentiometer that is proportional to the load shaft angle and is represented by variable θ_l .
8. Connect the *TACH* connector on the SRV02 to the *S3* socket on the UPM using the 6-pin-mini-DIN to 6-pin-mini-DIN cable. This connection is labeled #6 in Figure 22 and Figure 23. It carries the measured load shaft rate from the tachometer and is denoted by the variable ω_l .

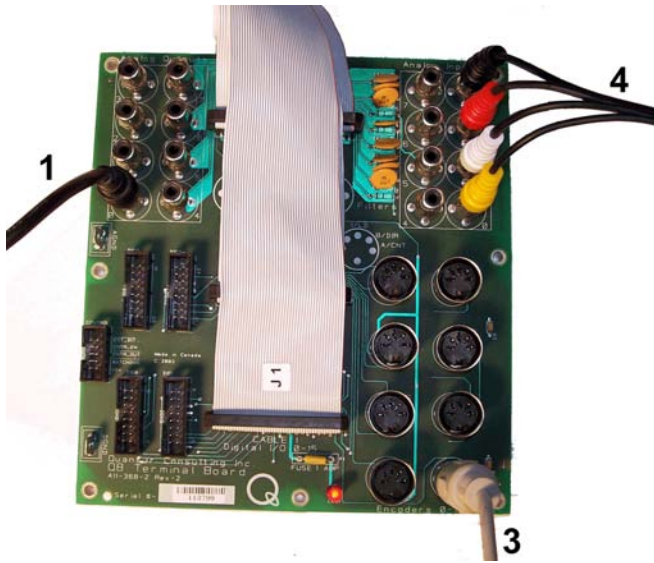


Figure 21: Connections on the Quanser Q8 Terminal Board.



Figure 22: Connections on the Quanser UPM-1503.



Figure 23: Connections on the Quanser SRV02 device.

Cable #	From	To	Signal
1	Terminal Board: Analog Output #0	UPM "From D/A" connector	Control signal to the UPM
2	UPM "To Load" connector	SRV02 "Motor" connector	Power leads to the SRV02 DC motor.
3	Terminal Board: Encoder Input #0	SRV02 "Encoder" connector	Encoder load shaft angle measurement.
4	UPM "To A/D" connector	Terminal Board: S1 to Analog Input #0 S2 to Analog Input #1 S3 to Analog Input #2 S4 to Analog Input #3	Carries the analog signals connected to the S1 & S2, S3, and S4 connectors on the UPM to the data-acquisition board.
5	UPM "S1 & S2" connector	SRV02 "S1 & S2" connector	Potentiometer load shaft angle measurement.
6	UPM "S3" connector	SRV02 "Tach" connector	Tachometer load shaft rate measurement.

Table 7 SRV02 system wiring summary when using the UPM.

6.3. Typical Connections with the Q3

This section describes the typical connections used to connect the SRV02 plant to the Q3 ControlPaQ-FW data-acquisition board, which has its own built-in amplifier. The connections are described in detail in the procedure below and summarized in Table 8.

Follow these steps to connect the SRV02 to the Q3:

1. Make sure everything is powered off before making any of these connections. This includes turning off your PC and the Q3.
2. Connect the 4-pin-stereo-DIN to 6-pin-stereo-DIN from *Motors #0* on the Q3 to the *Motor* connector on the SRV02. See connection #1 shown in Figure 24 and Figure 25. The cable transmits the controlled current that is applied to the SRV02 motor and is denoted I_m .
3. If the SRV02 has the -E option then the encoder can be used to measure the load shaft angle. Connect the 5-pin-stereo-DIN to 5-pin-stereo-DIN cable from the *Encoder* connector on the SRV02 panel to *Encoders #0* on the Q3 board, as depicted by connection #3 in Figure 24 and Figure 25. This carries the load shaft angle measurement and is denoted by the variable θ_l .
4. Connect the *TACH* connector on the SRV02 to the *S1 & S2* socket on the SRV02 using the 6-pin-mini-DIN to 6-pin-mini-DIN cable. This connection is labeled #3 in Figure 25. It carries the measured load shaft rate from the tachometer and is denoted by the variable ω_l .
5. Connect the free *S1 & S2* connector on the SRV02 to the *Analog In* socket on the Q3 board using the 6-pin-mini-DIN to 6-pin-mini-DIN cable. See connection #4 in Figure 24 and Figure 25.

25. This carries the voltage signals from both the potentiometer and the tachometer that is proportional to the load shaft angle and rate, respectively. The load shaft position measurement is represented by variable θ_1 and the rate is denoted by the variable ω_1 .



Figure 24: Connection on Q3.



Figure 25: Connections on SRV02 from Q3.

Cable #	From	To	Signal
1	Q3: Motors #0	SRV02 "Motor" connector	Power leads to the SRV02 DC motor.
2	Q3: Encoders #0	SRV02 "Encoder" connector	Encoder load shaft angle measurement.

<i>Cable #</i>	<i>From</i>	<i>To</i>	<i>Signal</i>
3	SRV02 "Tach" connector	SRV02 "S1 & S2" connector	Tachometer load shaft rate measurement.
4	SRV02 "S1 & S2" connector	Q3: Analog In	Potentiometer load shaft angle measurement and tachometer load shaft rate measurement.

Table 8 SRV02 system wiring summary when using the Q3.

7. Testing and Troubleshooting

This section describes some functional tests to determine if your SRV02 is operating normally. It is assumed that the SRV02 is connected as described in the Section 6.2, above. To carry out these tests, it is preferable if the user can use a software such as Quarc or LabVIEW to read sensor measurements and feed voltages to the motor. See Reference [3] to learn how to interface the SRV02 with Quarc. Alternatively, these tests can be performed with a signal generator and an oscilloscope.

7.1. Motor

7.1.1. Testing

Ensure the SRV02 motor is operating correctly by going through this procedure:

1. Apply a voltage to analog output channel #0 of the terminal board using, for example, the Quarc software.
2. The *motor* gear, component #4 shown in Figure 2, should rotate counter-clockwise when a positive voltage is applied and clockwise when a negative voltage is applied. Remark that the motor shaft and the load shaft turn in opposite directions.

7.1.2. Troubleshooting

If the motor is not responding to a voltage signal, go through these steps:

- Verify that the power amplifier is functional. For example when using the Quanser UPM device, is the red LED in the top-left corner lit?
- Check that the data-acquisition board is functional, e.g. the red LED on the Quanser Q4/Q8 terminal board should be bright red. The DAC board fuse may be burnt and need replacement.
- Make sure the voltage is actually reaching the motor terminals (use a voltmeter or oscilloscope).
- If the motor terminals are receiving the signal and the motor is still not turning, your motor might be damaged and will need to be repaired. Please see Section 8 for information on contacting Quanser for technical support.

7.2. Testing the Potentiometer

7.2.1. Testing

Test the SRV02 potentiometer with the following procedure:

1. Using a program such as Quarc, measure the analog input channel #0.
2. The potentiometer should output a positive voltage when the potentiometer gear, component #6 in Figure 2, is rotated counter-clockwise. The measurement should increase positively towards +5V until the discontinuity is reached, at which point the signal abruptly changes to -5V and begins to increase again.

7.2.2. Troubleshooting

Follow the steps below if the potentiometer is not measuring correctly:

- Verify that the power amplifier is functional. For example when using the Quanser UPM device, is the red LED in the top-left corner lit? Recall that the analog sensor signal goes through the UPM before going to the data-acquisition device. Therefore the UPM needs to be turned on to read the potentiometer.
- Check that the data-acquisition board is functional, e.g. the red LED on the Quanser Q4/Q8 terminal board should be bright red. If not then the DAC board fuse may be burnt and need replacement.
- Measure the voltage across the potentiometer. Ensure the potentiometer is powered with a $\pm 12V$ at the 6-pin-mini DIN connector and $\pm 5V$ at the potentiometer terminals, as described in Section 3.2.2. If the voltage from the wiper does not change when you rotate the potentiometer shaft, your potentiometer needs to be replaced. Please see Section 8 for information on contacting Quanser for technical support.

7.3. Tachometer

7.3.1. Testing

Test the tachometer on the SRV02 by performing the following:

1. Apply a 2.0 V signal to Analog Output Channel #0 in order to drive the motor.
2. Measure Analog Input Channel #2 to read the tachometer. When applying 2.0 V to the motor, the tachometer should be measuring a value of approximately 3.0 V.

7.3.2. Troubleshooting

If no signals are received from the tachometer, go through this method:

- Verify that the power amplifier is functional. For example when using the Quanser UPM device, is the red LED in the top-left corner lit? Recall that the analog sensor signal goes through the UPM before going to the data-acquisition device. It needs to be turned on to read from the tachometer.

- Check that the data-acquisition board is functional, e.g. the red LED on the Quanser Q4/Q8 terminal board should be bright red. If not then the DAC board fuse may be burnt and need replacement.
- Measure the voltage across the tachometer. When moving the load gear back and forth, is the voltage being measured changing? If not, then the tachometer needs to be replaced. Please see Section 8 for information on contacting Quanser for technical support.

7.4. Encoder

7.4.1. Testing

Follow this procedure to test the SRV02 encoder:

1. Measure Encoder Input Channel #0 using, for instance, the Quarc software.
2. Rotate the SRV02 load gear, component #5 in Figure 2, one rotation and the encoder should measure 4096 counts (or 8192 when using the SRV02-EHR option) in quadrature mode.

Note: Some data acquisition systems do not measure in quadrature and, in this case, one-quarter of the expected counts are received, i.e. 1024 counts in the SRV02-E or 2048 in the SRV02-EHR. In addition, some data acquisition systems measure in quadrature but increment the count by 0.25 (as opposed to having an integer number of counts). Make sure the details of the data-acquisition system being used is known. The counters on the Quanser DAC boards, such as the Q4 or Q8 systems, measure in quadrature and therefore a total of four times the number of encoder lines per rotation, e.g. a 1024-line encoder results in 4096 integer counts for every full rotation.

7.4.2. Troubleshooting

If the encoder is not measuring properly, go through this procedure:

- Check that the data-acquisition board is functional, e.g. the red LED on the Quanser Q4/Q8 terminal board should be bright red. If not, then the terminal board or DAC board fuses may be burnt and need replacement.
- Check that both the A and B channels from the encoder are properly generated and fed to the data-acquisition device. Using an oscilloscope, there should be two square waves, signals A and B, with a phase shift of 90 degrees. If this is not observed then the encoder may be damaged and need to be replaced. Please see Section 8 for information on contacting Quanser for technical support.

8. Technical Support

To obtain support from Quanser, go to <http://www.quanser.com/> and click on the *Tech Support* link. Fill in the form with all the requested software and hardware information as well as a description of the problem encountered. Also, make sure your e-mail address and telephone number are included. Submit the form and a technical support person will contact you.

Note: Depending on the situation, a support contract may be required to obtain technical support.

9. References

- [1] Quanser. *Q4/Q8 User Manual*.
- [2] Quanser. *SRV02 User Manual*.
- [3] Quanser. *Rotary Experiment #0: SRV02 Quarc Integration*.

Appendix A: Motor Specification Sheet

Series 2338 ... S

See beginning of the Motor Section for Ordering Information

		2338 S	4.5 S	006 S	009 S	012 S	018 S	024 S	
1	Nominal voltage	U_N	4.5	6	9	12	18	24	Volt
2	Terminal resistance	$R \pm 12\%$	1.4	2.6	5.7	10.0	23.5	38.0	Ω
3	Output power	$P_2 \text{ max.}$	3.39	3.23	3.29	3.31	3.18	3.50	W
4	Efficiency	$\eta \text{ max.}$	70	69	67	66	67	67	%
5	No-load speed	$n_o \pm 12\%$	7,200	7,200	7,400	7,800	7,400	7,600	rpm
6	No-load current (with shaft \varnothing 0.12 in)	$I_o \pm 50\%$	0.100	0.080	0.060	0.050	0.030	0.025	A
7	Stall torque	M_H	2.55	2.42	2.41	2.29	2.32	2.49	oz-in
8	Friction torque	M_R	0.082	0.086	0.095	0.099	0.095	0.102	oz-in
9	Speed constant	k_n	1,650	1,240	855	678	428	330	rpm/V
10	Back-EMF constant	k_E	0.606	0.804	1.170	1.470	2.340	3.030	mV/rpm
11	Torque constant	k_M	0.818	1.088	1.586	1.997	3.158	4.107	oz-in/A
12	Current constant	k_i	1.222	0.919	0.630	0.501	0.317	0.244	A/oz-in
13	Slope of n-M curve	$\Delta n/\Delta M$	2,824	2,975	3,071	3,406	3,190	3,052	rpm/oz-in
14	Rotor inductance	L	100	180	380	630	1,400	2,600	μH
15	Mechanical time constant	τ_m	20	17	17	17	17	17	ms
16	Rotor inertia	J	$6.797 \cdot 10^{-5}$	$5.523 \cdot 10^{-5}$	$5.240 \cdot 10^{-5}$	$4.815 \cdot 10^{-5}$	$5.098 \cdot 10^{-5}$	$5.381 \cdot 10^{-5}$	oz-in-sec ²
17	Angular acceleration	$\alpha \text{ max.}$	38	44	46	48	46	47	$\cdot 10^3 \text{ rad/s}^2$
18	Thermal resistance	R_{th1} / R_{th2}	3 / 24						$^{\circ}\text{C/W}$
19	Thermal time constant	τ_{w1} / τ_{w2}	5.7 / 645						s
20	Operating temperature range:								
	– motor		– 30 to +85 (– 22 to +185)						$^{\circ}\text{C}$ ($^{\circ}\text{F}$)
	– rotor, max. permissible		+125 (+257)						$^{\circ}\text{C}$ ($^{\circ}\text{F}$)
	Note: Special operating temperature models for		–55 $^{\circ}\text{C}$ to +125 $^{\circ}\text{C}$ (– 67 $^{\circ}\text{F}$ to +257 $^{\circ}\text{F}$) available on request.						
21	Shaft bearings		sintered bronze sleeves		ball bearings		ball bearings, preloaded		
22	Shaft load max.:		(standard)		(optional)		(optional)		
	– with shaft diameter		0.1181		0.1181		0.1181		in
	– radial at 3,000 rpm (0.12 in from bearing)		9		72		72		oz
	– axial at 3,000 rpm		1.08		7.2		7.2		oz
	– axial at standstill		72		72		72		oz
23	Shaft play:								
	– radial	\leq	0.0012		0.0006		0.0006		in
	– axial	\leq	0.0079		0.0079		0		in
24	Housing material		steel, zinc galvanized and passivated						
25	Weight		2.47						oz
26	Direction of rotation		clockwise, viewed from the front face						
Recommended values									
27	Speed up to	$n_e \text{ max.}$	6,000	6,000	6,000	6,000	6,000	6,000	rpm
28	Torque up to	$M_e \text{ max.}$	0.566	0.566	0.566	0.566	0.566	0.566	oz-in
29	Current up to (thermal limits)	$I_e \text{ max.}$	1.380	1.000	0.680	0.510	0.330	0.260	A

Appendix B: Tachometer Specification Sheet

Series 2251 ... S

See beginning of the Section for Ordering Information

Characteristics of the DC-Motor-Tacho Combination

Series	mechanical time constant τ_m	moment of inertia J	angular acceleration α_{max}	frequency	weight response
2251 U 4.5 S 1.5 G	16 ms	$4.93 \cdot 10^{-5}$ oz-in-sec ²	$52 \cdot 10^3$ rad s ⁻²	1,500 Hz	3.21 oz
2251 U 006 S 1.5 G	15 ms	$3.68 \cdot 10^{-5}$ oz-in-sec ²	$56 \cdot 10^3$ rad s ⁻²	1,500 Hz	3.21 oz
2251 U 012 S 1.5 G	16 ms	$4.12 \cdot 10^{-5}$ oz-in-sec ²	$56 \cdot 10^3$ rad s ⁻²	1,500 Hz	3.21 oz
2251 U 024 S 1.5 G	15 ms	$2.65 \cdot 10^{-5}$ oz-in-sec ²	$59 \cdot 10^3$ rad s ⁻²	1,500 Hz	3.21 oz

The characteristics of the DC-Micromotor Series 2233 ... S, can be veived on the corresponding motor specification page.

Tachogenerator

1.5 G

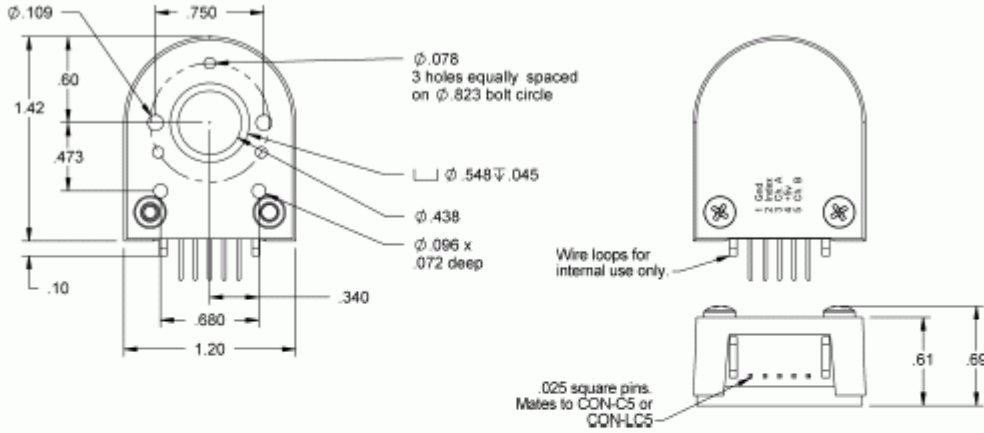
EMF constant	K_E	1.5	mV/rpm
		14,325	mV/rad s ⁻¹
Tolerance of EMF constant		± 2	%
Load resistance	R_L	≥ 25	kΩ
Operating speed, max. continuous	$n_{0 max}$	≤ 5,000	rpm
Terminal resistance	R	260	Ω
Ripple, peak-peak, typical		7	%
Ripple frequency, cycles		14	per turn
Linearity, without load, between 500 and 5,000 rpm		± 0.2	%
Reversion error		± 0.2	%
Temperature coefficient of EMF		0.02	% / °C
Temperature coefficient of armature resistance		0.4	% / °C
Rotor inductance	L	3,000	μH
Direction of rotation		reversible	
Polarity		dependent on direction of rotation	

Appendix C: Potentiometer Specification Sheet

ELECTRICAL SPECIFICATIONS		
PARAMETER	MIL-PRF-12934/MIL-PRF-39023 TEST PROCEDURES APPLY	
Total Resistance: Model 132 Wirewound Tolerance: 50Ω and above Below 50Ω Model 138 Conductive Plastic Tolerance: Model 139 Cermet Tolerance:	STANDARD 5Ω to 20KΩ ± 3% ± 5% 1KΩ to 50KΩ ± 10% 500Ω to 2MΩ ± 20%	SPECIAL to 35KΩ ± 1% ± 3% – ± 5% – ± 5%
Linearity (Independent) Total Resistance (132) 5Ω to 20Ω 20Ω to 200Ω 200Ω and above 138/139	STANDARD ± 1.0% ± 1.0% ± 0.5% ± 0.5%	BEST PRACTICAL ± 0.75% ± 0.50% ± 0.25% ± 0.25%
Noise (132)	100Ω ENR	
Output Smoothness (138 & 139)	0.1% maximum	
Power Rating Model 132 Model 138 Model 139	40°C Ambient 2.75 watts 2 watts 5 watts All Models derated to zero at 125°C	
Electrical Rotation Continuous Stops	MODEL 132 352° ± 2° 336° ± 2°	MODEL 138 345° ± 4° 336° ± 4°
Insulation Resistance	1000MΩ minimum at 500VDC	
Dielectric Strength	1000V _{RMS} , 60Hz	
Absolute Minimum Resistance	1.0% of total resistance or 0.5Ω whichever is greater (132 only)	
Minimum Voltage	0.5% maximum	
Temperature Coefficient of Resistance 132 138 139	Refer to standard resistance element data ± 500ppm/°C maximum ± 100ppm/°C maximum	

Appendix D: Encoder Specification Sheet

Mechanical Drawing:



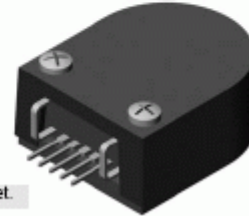
Mechanical Specifications:

Parameter	Dimension	Units
Moment of Inertia	8.0×10^{-8}	oz-in-s ²
Hub Set Screw Size	3-48 or 4-48	In.
Hex Wrench Size	.050	In.
Encoder Base Plate Thickness	.135	In.
3 Mounting Screw Size	0-80	In.
2 Mounting Screw Size	2-56 or 4-40	In.
3 Screw Bolt Circle Diameter	$.823 \pm .005$	In.
2 Screw Bolt Circle Diameter	$.750 \pm .005$	In.
Required Shaft Length	.445 to .570*	In.
With E-option	.445 to .795*	In.
With H-option	>.445*	In.

* Add .125" to the required shaft length when using R-option.

Pin-out:

Pin	Description
1	Ground
2	Index
3	A channel
4	+5VDC power
5	B channel



Electrical Specifications:

For complete details see the EM1 / HEDS data sheet.

Phase Relationship:

B leads A for clockwise shaft rotation, and A leads B for counterclockwise rotation viewed from the cover/label side of the encoder (see the EM1 / HEDS data sheet).