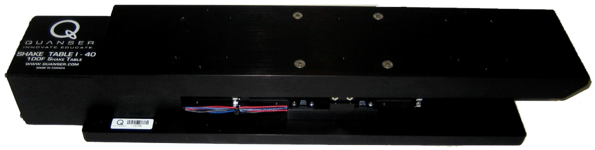

Shake Table I-40

User Manual

STI-40

Quanser Inc.

2012

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CE Compliance CE

This product meets the essential requirements of applicable European Directives as follows:

- 2006/95/EC; Low-Voltage Directive (safety)
- 2004/108/EC; Electromagnetic Compatibility Directive (EMC)

CONTENTS

1 PRESENTATION

The Shake Table I-40 (STI-40) system is illustrated in Figure 1.1. The stage is mounted on a high-quality, low backlash linear guide with a total travel of 40.0 mm (i.e., $\pm$ 20.0 mm) and is driven using a ball-screw drive mechanism. Using the high torque direct drive motor, the stage loaded with a 1.5 kg mass can be accelerated up to 1.0 g (i.e., 9.81 m/s^2). The high-resolution encoder enables the system to obtain a linear stage position resolution of 1.22 μm. The main devices needed to run the shake table is a power amplifier (e.g., VoltPAQ), a data acquisition (DAQ) device (e.g., Quanser Q2-USB), and a PC running the QUARC®control software.

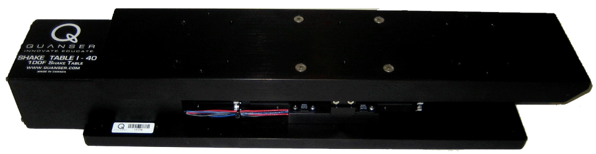


Figure 1.1: Shake Table I-40

This system can be used to simulate earthquakes and evaluate the performance of active mass dampers, e.g., using the Quanser One-Floor Active Mass Damper (AMD-1) system described in [**?**] and shown in Figure 1.2. As a typical application, the Shake Table I can excite the flexible modes of a tall structure in order to design, implement, and evaluate a control system to manipulate and dampen the structural vibrations.

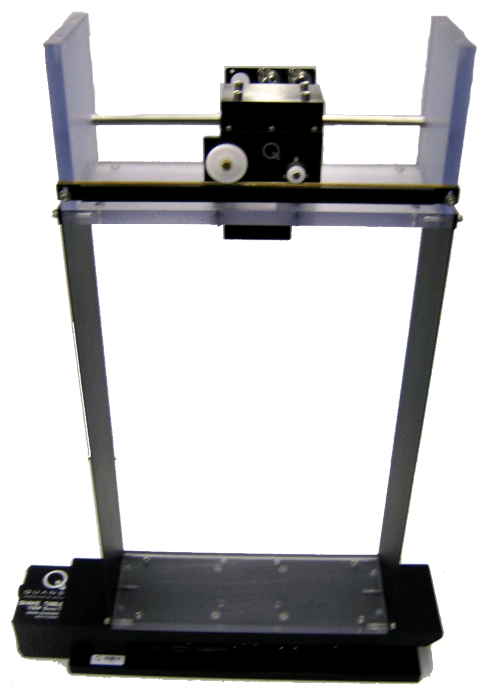


Figure 1.2: Shake Table I-40 with AMD-1

⚠ **Caution: This equipment is designed to be used for educational and research purposes and is not intended for use by the general public.** The user is responsible to ensure that the equipment will be used by technically qualified personnel only.

2 SYSTEM DESCRIPTION

2.1 Component Nomenclature

As a quick nomenclature, Table 2.1 provides a list of all the principal elements composing the Shake Table I-40 system. Every element is located and identified, through a unique identification (ID) number, on the Shake Table I plant represented in Figure 2.1 and Figure 2.2.

ID #	Description	ID #	Description
1	Base Plate	8	Encoder Cable Connector
2	Linear Guide	9	Motor Cable Connector
3	Table Position Indicator	10	Limit Switch Connector
4	Left Limit Switch	11	Power LED
5	Right Limit Switch	12	Left Limit Switch LED
6	Top Stage	13	Right Limit Switch LED
7	Motor/Encoder Case		

Table 2.1: Shake Table I-40 component nomenclature

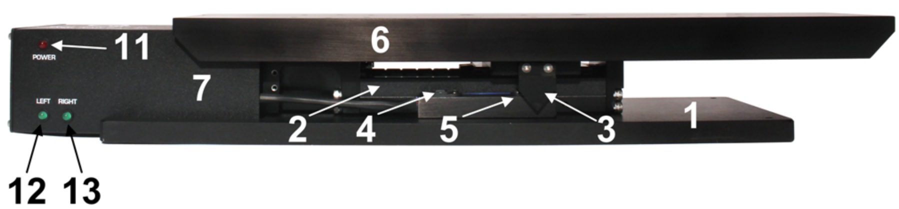


Figure 2.1: Shake Table I-40 components - front view.

Figure 2.2: Shake Table I-40 components - side view

2.2 Component Description

This section provides a description of the individual elements comprising the Shake Table I-40 system.

2.2.1 Shake Table

The Shake Table I-40 overall dimensions are shown in Table 2.2. The length measured is from the start of the DC motor case to the end of the top stage when the stage is at the maximum right position, i.e., maximum length of device.

Description	Value	Unit
Length	57.5	cm
Width	12.7	cm
Height	7.62	cm
Total Mass	5.88	kg

Table 2.2: Shake Table I-40 Dimensions and Mass

2.2.2 Top Stage

The dimensions of the top stage is 17.0 $\times$ 4.0 inch^2, or 43.2 $\times$ 10.2 cm^2, as described in Table 2.3, below.

Description	Value	Unit
Length	43.2	cm
Width	10.2	cm
Total Mass	0.7	kg

Table 2.3: Top Stage Dimensions and Mass

2.2.3 DC Motor

The DC motor used for the Shake Table I-40 is the *Magmotor S23 Brushed Servo Motor* with a stack length of 100. The main motor specifications that are relevant to controlling the table are listed in Table 2.4. See *Magmotor s23* manufacturer sheet for more motor specifications.

⚠ **Caution:** *High-frequency signal applied to a motor will eventually damage the gearbox motor and 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 50 Hz.

⚠ **Caution:** Input ± 15 V, 3 A peak, 1 A continuous.

2.2.4 Position Measurement: Optical Encoder

The linear position of the stage is obtained using a high-resolution rotary optical encoder coupled to the linear screw of the linear guide. Specifically, it is a *US Digital E3-2048-250-N-H-D-B* encoder. When used in quadrature mode, the encoder outputs 8192 counts per revolution of the shaft. Using this encoder, the effective linear position resolution of the top stage is 1.22 μm.

2.2.5 Power Amplifier

The Shake Table I can be driven using the Quanser VoltPAQ-series amplifier. The VoltPAQ is a linear voltage-controller amplifier. For more details, see the VoltPAQ User Manual.

2.2.6 Data-Acquisition Board

Various data-acquisition boards can be used with the VoltPAQ power amplifier and Shake Table I, e.g. the Quanser Q2-USB or Q8-USB DAQ boards. Please go to the corresponding manual for details regarding your data-acquisition system.

2.2.7 Linear Guide

The top stage of the Shake Table I-40 is mounted on the *Misumi LX3010C-B1-T3056.4-150* single-axis actuator. It is a covered single-axis linear guide with a rail length of 150 mm and has a lead-screw pitch of 10 mm. See the *MISUMI Single Axis Actuators* specification sheet for additional information.

2.2.8 Limit Switches

The *Left* and *Right* proximity sensors are shown in Figure 2.1 with ID #4 and #5, respectively. The *Left* or *Right* limit switch gets triggered when the top stage moves close to the left or right mechanical range. These sensors are used to stop the controller when the table exceeds its stroke. They are also used to calibrate the stage to its center, mid-stroke position.

2.3 System Parameters

The specifications on the Shake Table I-40 model parameters are given in Table 2.4.

Description	Value	Unit
DC Motor		
Current-torque constant	0.0918	N-m/A
Back-emf constant	0.0917	V/(rad/s)
Maximum peak current	24.0	A
Maximum continuous current	3.0	A
Armature resistance	1.45	Ω
Rotor Moment of inertia	4.319×10^{-5}	kg-m^2
Table Assembly		
Table travel (end-to-end)	40.0	mm
Preload mass (i.e. table assembly mass)	2.62	kg
Lead screw pitch	10	mm/rev
Optical Encoder		
Encoder line count	2048	lines/rev
Encoder line count (in quadrature)	8192	counts/rev
Encoder linear resolution (in quadrature)	1.22	μm/count
Encoder type	TTL	
Encoder signals	A, B, Index	
Current Sense		
Current sense gain	1	V/A

Table 2.4: Shake Table I-40 Specifications

3 HARDWARE SETUP

This section describes the standard wiring procedure for the Shake Table I-40 plant. The following hardware is required:

- **Power Amplifier**: Quanser VoltPAQ-X1, or equivalent.
- **Data Acquisition Device**: Quanser Q1-cRIO, Q2-USB, Q8-USB, QPID/QPIDe, NI DAQ, or equivalent.
- **Shake Table Plant**: Quanser Shake Table I-40 (STI-40).

Caution: When using a Quanser VoltPAQ power amplifier, **make sure you set the Gain to 3**!

Caution: **If the equipment is used in a manner not specified by the manufacturer, the protection provided by the equipment may be impaired.**

3.1 Cables

The cables supplied with the Shake Table I-40 system are described in Table 3.1. Depending on your configuration, not all these cables are necessary.

3.2 Wiring Procedure

The connections between the data acquisition device, the power amplifier, the Shake Table I plant, and the One-Floor Active Mass Damper (AMD-1) is illustrated in Figure 3.1 and summarized in Table 3.2. If you are NOT using the AMD-1, then you can omit those corresponding connections.

Note: The wiring diagram shown in Figure 3.1 is using a generic data acquisition device. The same connections can be applied for any data acquisition system that has 1x analog input, 2x analog output, 2x encoder input, and 1x Digital Input header.

Caution: **Perform all connections with the PC and the amplifier turned OFF!**

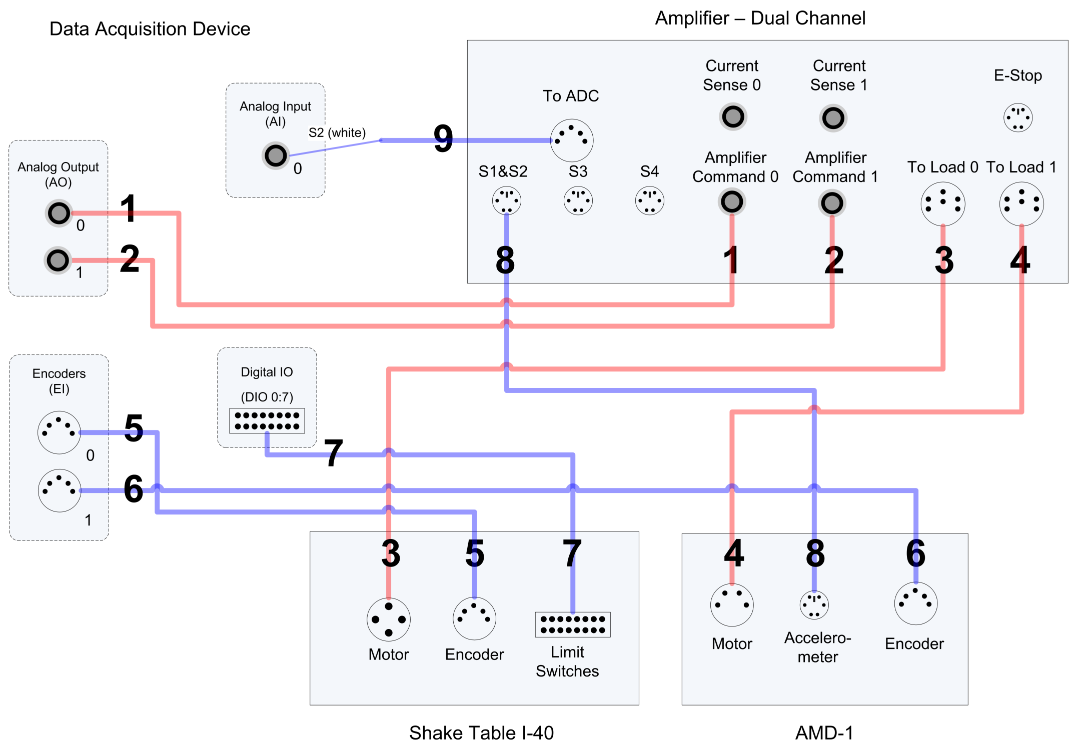


Figure 3.1: Shake Table I-40 Connections when using One-Floor Active Mass Damper

Connectio	From	To	Signal
1	DAQ: Analog Output #0	Amplifier *Amplifier Command 0*	RCA Cable: control signal to the amplifier for Shake Table I.
2	DAQ: Analog Output #1	Amplifier *Amplifier Command 1*	RCA Cable: control signal to the amplifier for AMD-1.
3	Amplifier *To Load 0*	STI-40: *Motor Connector*	Motor Cable: power leads from the amplifier to the DC motor.
4	Amplifier: *To Load 1*	AMD-1: *Motor* Connector	Motor Cable: power leads from the amplifier to the DC motor.
5	DAQ: Encoder Channel #0	STI-40: Encoder Connector	Encoder Cable: table linear position feedback signal.
6	DAQ: Encoder Channel #1	AMD-1 *Encoder* Connector	Encoder Cable: AMD cart position feedback signal.
7	DAQ: *DIO 0:7* Header	STI-40: Limit Switches Connector	Digital I/O Ribbon Cable: *Left* and *Right* limit switches
8	AMD-1: Accelerometer Connector	Amplifier: *S1&S2* connector	Analog Cable: connects AMD-1 first floor acceleration to amplifier S1&S2 connector.
9	Amplifier: *To ADC* connector	DAQ: Yellow RCA (S1) to Analog Input #0	5-pin-DIN to 4x RCA cable: connects AMD-1 first floor acceleration (in S1 yellow RCA cable) to DAQ device.

Table 3.2: Shake Table I with AMD-1 system wiring

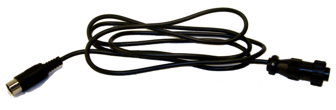
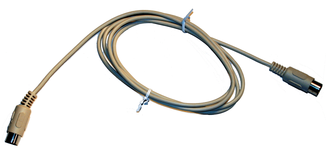
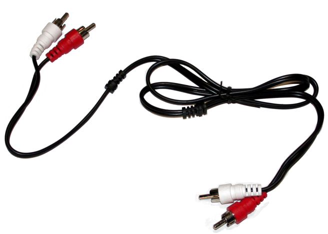
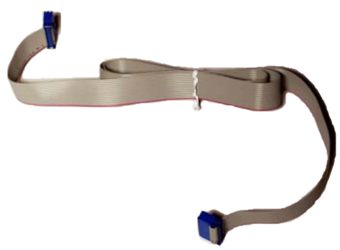
<table>
<tr><th>Cable</th><th>Description</th></tr>
<tr><td>
(a) Motor Cable</td><td>The Motor cable carries the power leads from the power amplifier (e.g., VoltPAQ) to the shake table DC motor.</td></tr>
<tr><td>
(b) Encoder Cable</td><td>The Encoder cable carries encoder signals and required DC power supply.</td></tr>
<tr><td>
(c) RCA Cable</td><td>The RCA cable comprises two sets of RCA male connectors. One connects an analog output of the data acquisition (DAQ) device to the power amplifier to drive the motor. The other can be used to carry the current sense signal from the amplifier back to the DAQ device, where the signal is then available to be monitored.</td></tr>
<tr><td>
(d) Digital Cable</td><td>The Digital I/O cable connects from the Shake Table I-40 limit sensors to the DAQ device.</td></tr>
<tr><td>
(e) Analog Cable</td><td>The Analog cable is a 6-pin mini-DIN to 6-pin mini-DIN cable that can be used to connect any potential plant sensor, e.g., accelerometer or strain-gage. It can provide a ± 12 V bias to analog sensors and carry their voltage signals to the DAQ.</td></tr>
<tr><td>
(f) 5-pin-DIN to 4xRCA Cable</td><td>Connects the analog sensors that are wired to the S1&S2, S3, and S4 connectors on the power amplifier to the DAQ.</td></tr>
</table>

Table 3.1: Supplied Cables

4 TESTING AND TROUBLESHOOTING

This section describes some functional tests to determine if your Shake Table I-40 is operating normally. It is assumed that the Shake Table I-40 is connected as described in the Section 3.2, 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. Alternatively, these tests can be performed with a signal generator and an oscilloscope.

4.1 Motor

4.1.1 Testing

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

1. Manually position the stage in the center position between the two limit switches.
2. Apply a voltage to analog output channel #0. Start with 0.33 V and slowly increase it.
   Note: This assumes the amplifier gain is set to 3 V/V, thus setting AO #0 to 0.33 V applies 1 V to the motor.
3. The stage should begin moving when between 1.5 V to 2 V is applied.

4.1.2 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 VoltPAQ device, is the green LED lit?
- Check that the data acquisition device is functional, e.g., ensure it is properly connected, that the fuse is not burnt.

4.2 Encoder

4.2.1 Testing

Follow this procedure to test the encoder:

1. Manually move the stage to one of the end limits.
2. Start measuring Encoder Input Channel #0.
   Note: If using the Q2-USB, make sure you are using the Inverse Modulus function as done in the supplied controller files. Otherwise, your measured counts will be discontinuous.
3. Manually move the top stage to the other end limit (e.g., from left to right).
4. If you move the stage from end to end, it should give approximatly 49152 counts.

   textbfCalculation: Given that total travel is about 60 cm and the lead screw pitch is 10 cm/rev, the encoder would rotate 6 times. The encoder resolution in quadrature is $4 \times 2048 = 8192$ counts/rev. Therefore it should go through $6 \times 8192 = 49152$ counts (when the stage is move from end to end).

4.2.2 Troubleshooting

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

- Check that the data-acquisition board is functional, e.g., ensure it is properly connected, that the fuse is not burnt.
- 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 5 for information on contacting Quanser for technical support.

4.3 Active Mass Damper

Please go to the One-Floor Active Mass Damper (AMD-1) User Manual ([**?**]) for troublehsooting information.

5 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.