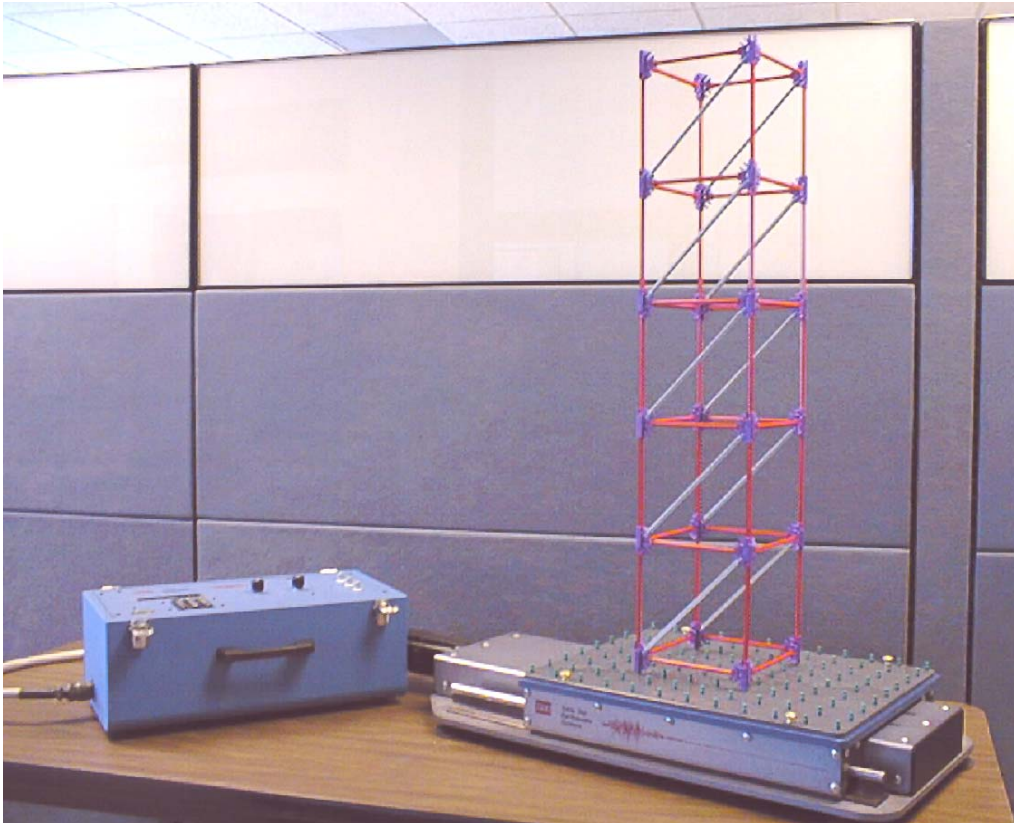


MTS Tabletop Earthquake System



Introduction

The MTS Table Top Earthquake System is an interactive teaching tool for demonstrating the affects of earthquakes and vibrations on structures. Ease of use, safety, and advanced performance features make this system ideally suited for classroom demonstrations and hands on learning experiences. This portable and user friendly system is a great way to qualitatively investigate the dynamic response of structures to horizontal motions, both harmonic and recorded earthquake time histories. For young students, just learning about earthquakes or structures, demonstrations and structural competitions in the classroom bring to life the concept of dynamic behavior. For more advanced users, an external input for analog displacement signals and the displacement and acceleration reference signals are available.

This manual describes the care and use of the earthquake system. Please read it thoroughly to get the best use of the system and keep it in good condition. There is an operational review (Quick Start Guide) on page 8.

Read and understand the following warnings before setting up and running your Tabletop Earthquake System!

Warning!

Moving parts

- **This is a dynamic system. Be aware that the table can move unexpectedly and rapidly.**
- **Do not operate unless the shake table is mounted on a flat, solid surface**
- **Do not lift or tip the system with power applied. There are exposed pinch points on the bottom of the system.**
- **Do not operate without all guards in place.**
- **Children must not use the system without adult supervision.**

Warning!

Electric shock.

- **Line voltage (115VAC) inside the control box**
- **Do not open the control box with power supplied**
- **Keep controller and motor away from liquids**

System Components

Earthquake table assembly

The earthquake table consists of a flat table surface mounted on linear bearings. A drive mechanism composed of a brushless servomotor and a rotary to linear actuator produces horizontal motions in response to commands from the controller.

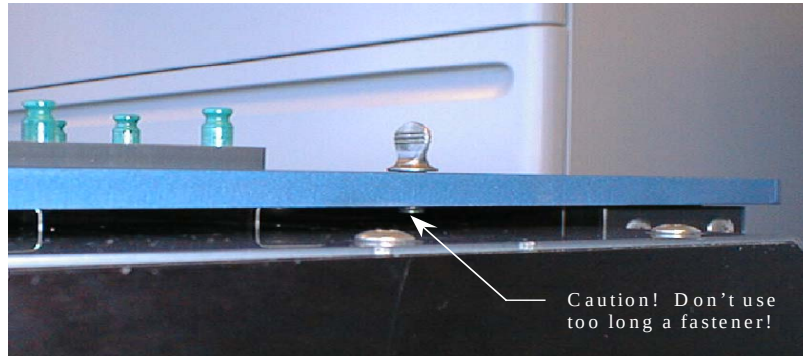


Table assembly- - ready to run

Table interface

$\frac{1}{4}$ -20 UNC threads on a 2" grid. The tabletop is $\frac{3}{8}$ inch thick.

Caution : Do not use mounting screws that project below the table surface. Damage to the system can result. If students are using the system, it is a good idea to only have the appropriate length of fasteners available to them. Do not use specimens that can spill liquids onto or into the table mechanism.



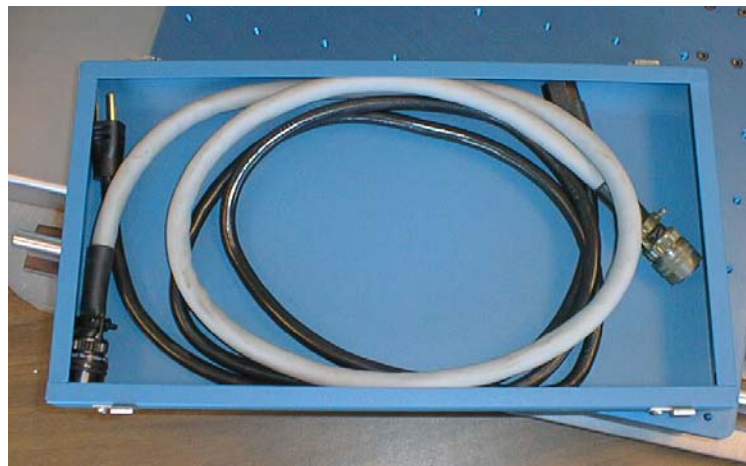
Control box

The control box contains the motor drive amplifier, a low voltage power supply and the digital controller card. No user adjustments are required or advised.

Cables



The two cables are stored in the lid of the control box. The lid should be removed by sliding the hinges off the pins. Note: When re-storing the cables in the lid, arrange them so that they do not get pinched between the lid and the controller knobs. Don't force the lid closed, rearrange the cables so that it closes easily.



Cable storage in lid

System Specifications

Table dimensions	13 in x 17 in (¼-20UNC mounting holes on 2" x 2" grid)
Design Payload	5 -15 lbm
Maximum Payload	25 lbm
Frequency range	0.1-20 Hz.
Displacement	±3.2 inches
Velocity	±20 inches/second
Acceleration	±1.0 g (with 25 lbm specimen)
Total weight of system	< 60 lb
Overall dimensions	14"W x 36" L x 4"H

System Set-up

Place the shake table on a clean, smooth, flat surface. The table assembly weighs approximately 60 lbm, so a sturdy table or desk is desirable. When in operation, the table will exert a dynamic, horizontal force on the desktop. A unique feature of this shaking table system is the internal counterbalance system, which minimizes the vibration imparted to the tabletop. It is optimized for a five pound rigid specimen. A heavier or lighter specimen, or a flexible specimen, will result in some vibration input into the table. Despite the internal counter balance, a resonant response of the table can be expected at certain frequencies. Be prepared! The feet of the system are actually suction cups, to minimize slipping and overturning, but the table should be kept back from the edges of the table, just to be sure.

Note: When moving or lifting the table, break the suction of the feet by lifting the edge of each cup with your finger.

Choose a nearby location for the control box, with convenient routing for the motor cable. Be careful that the cable is clear of users, so that the controller is not accidentally pulled off the table. If tall or fragile structures are to be tested, protect the control box from falling parts by placing it sufficiently distant from the table. .



Connect the motor cable

The motor cable has keyed, bayonet style connectors. Align the keys when connecting the cable, don't force them. The black connector matches the black cable on the motor, the green connector goes to the control box.

Connect the power cable to 120V, single phase power. (10A maximum)

Use only a three prong, grounded outlet. Failure to use a properly grounded outlet can result in poor motion control and/or electric shock.



Power switch, fuse and cord connector

Quick Start Guide

Refer to the detailed operation description in this manual for a more complete description of operation.

Turn on power

The rocker switch is on the right side of control box.

Calibrate the system

After a few seconds, the controller will beep and a message will appear. Hit any key on the keypad to calibrate, and the system will slowly move to full stroke and over-drive for a few seconds. This allows the table and counter-mass to synchronize and the encoder to be homed.

Note: This process may need to be repeated if force limits are exceeded. See Mode 4 (Service) below.

Choose the desired mode:

1 Set point

This mode allows arbitrary motion, following the position of the set point knob. High rates of knob input may result in excessive acceleration. If the table starts to hit the end stops, the drive system has slipped. This does not damage the system, but the system should be re-calibrated. (see 4, below)

2 Sine Function Generation

This mode allows resonant searches of the structure specimen. Frequency and amplitude can be continuously adjusted as the specimen response is observed. Two modes are provided...Constant Displacement and Constant Velocity. The internal function generator has a frequency range of 0.1 to 20 Hz, adjustable with the Freq. knob. Change the frequency slowly to avoid sudden steps in frequency. Best results are obtained when the frequency and amplitude are adjusted simultaneously, in Displacement mode.

3 Earthquake playback

Several earthquake records have been stored on two flash memory chips in the controller. Flash 1 has some North American quakes. Flash 2 has some Asian quakes. Each file has been high pass filtered to fit within the displacement and velocity limitations of the system, however, the dynamic characteristics of the motion are well preserved for comparative purposes. Note: There is room on these flash memory chips for many more additional earthquakes. See elsewhere in the manual for details on loading additional files.

4 Service

The service mode offers several options:

0 Exit

- 1 Flash memory function
Clear, and load time histories. This requires a password to prevent accidental clearing by students. See Appendix for details.
- 2 Re-calibrate. Can also be accomplished by cycling the power on the controller
- 3 Select external input for program. This is a BNC on the top panel of the controller.
($\pm 8V = \pm 2.5$ inch displacement)
- 4 (*not shown on screen display*) Switches the signal at Output 1 (BNC) to Displacement Command. It is normally Acceleration Command

Shaking Table Controller Operation

When the shaking table controller is turned on, the Liquid Crystal Display (LCD) shows the following message:

**Shaker Table READY
Push Key to CALIBRATE**

Pushing any key on the keypad starts the Calibration process. The shaking table uses a relative displacement encoder, and therefore, must calibrate absolute position every time the controller turns on. During the calibration process, the controller will slowly move the table to the other end away from the motor and will continue to run and slip the drive mechanism until the right encoder value is achieved. Then the controller will retract the table to the center (zero) position. While calibrating, the controller displays:

**Shaker Table READY
NOW CALIBRATING**

At the end of calibration, the controller displays the following message for 1.5 seconds:

**Shaker Table READY
CALIBRATION COMPLETE**

Then, the controller Main Menu appears:

**SETPOINT=1, SINE WAVE=2
QUAKE =3, SERVICE =4**

Pushing the Option Number on the keypad selects that option. Any other key results in the buzzer sounding a low BAD buzz.

Option 1 – Setpoint Mode

Selecting Option 1 puts the shaker table into Setpoint control where the amplitude potentiometer is used as a manual positioning control. The potentiometer has built-in limits of +/-100% of stroke (+/-2.5 inches). When the user pushes any key on the keypad, the controller will slowly ramp to the current value of the amplitude potentiometer shown on the 2nd line of the LCD:

**PUSH ANY KEY TO START
44%**

Prior to pushing any key, turning the amplitude potentiometer will change the percentage readout accordingly. As soon as a key is pushed, the controller displays:

MOVING TO THIS VALUE

44%

Turning the potentiometer will move the table to the position shown on the display:

POTENTIOMETER VALUE

88%

To exit this mode, push any key on the keypad again. The controller will then ramp the displacement to zero (center) position while displaying:

MOVING TO ZERO

14%

After reaching zero, the Main Menu is then shown again.

Option 2 – Sine Wave Mode

Selecting Option 2 puts the shaker table into sine wave command mode where the motion is controlled by both the amplitude and frequency potentiometers. The amplitude potentiometer controls the command % from 0-100% and the frequency potentiometer controls the frequency from 0.05 to 20.0 Hertz. The amplitude increment is in 1% increments. With the exception of the low end of 0.05 Hertz, the frequency is adjustable in 0.1Hertz increments. The first prompt for this mode is for selection of sine wave mode type:

DISPLACEMENT MODE = 1
VELOCITY MODE = 2

In displacement mode, the sine wave command output level is EXACTLY what the amplitude potentiometer setting is. In velocity mode, the amplitude potentiometer is used to scale a sine wave whose output value changes with 1/frequency. In mode 2, the user is prompted for the output amplitude in % for 1.0 Hertz. Any positive value is acceptable, but it should be noted that the controller will saturate the output at 100% when the frequency is low enough. For example, if 50% is entered for the 1.0 Hertz value and the amplitude potentiometer is set to 100%, the output at 1.0 Hertz will be 50%. Then, if the frequency is lowered to 0.5 Hertz, the output rises to 100%. Likewise, if the frequency is raised to 2.0 Hertz, the output drops to 25%. In both modes, the user gets to select when to start running the sine waves by pushing the [#] key on the keypad. The [0] (zero) key aborts the sine wave back to the Main Menu. The controller will change amplitude and frequency as set by the potentiometers during running of the sine wave commands.

Option 3 – Earthquake Mode

Selecting Option 3 puts the controller in the earthquake time history playback mode. The first prompt asks for which flash memory to search for an earthquake to run. After selecting a flash memory (#1 or #2), the controller will show the name of the 1st earthquake stored in the flash memory. If no entries exist, the controller will display an error message and ask the user to enter a number again. The user may ALWAYS enter a [0] (zero) key to exit back to the Main Menu if there are NO earthquakes stored. If at least one

earthquake record exists, the user is then prompted to answer with the [#] key to run that earthquake, the [1] (one) key to scroll to the next earthquake entry in the flash memory, or [0] (zero) key to exit to the Main Menu. If the user selects scroll, the controller will scan to the next earthquake record and show it's name. If no more records exist, the controller will go back and show the 1st earthquake's name again. After selection of an earthquake, the user is prompted to start the earthquake, showing the current amplitude in %. The amplitude potentiometer can be changed during the playback and the controller will follow any changes.

Option 4 – Service Mode

Option 4 of the Main Menu is for service operations on the shaking table controller. The Service Menu prompt is:

**EXIT =0, FLASH FCN=1
RE-CAL =2, EXT INPUT=3**

Selection of Flash Functions (key [1]), allows the user to control the flash memories:

**EXIT =0, CLR FLASH=1
LD FLASH=2, DIR FLASH=3**

Flash Memory Functions [1]

If the user selects clear flash memory ([1] key), the controller will first ask which flash memory to erase:

**ABORT =0,
ERASE FLASH 1/2 ?**

Then, to make absolutely sure that this is what the user wants to do, the controller will verify the request by asking:

**ERASE FLASH #1, ABORT=0
ARE YOU SURE = 1**

or

**ERASE FLASH #2, ABORT=0,
ARE YOU SURE = 1**

Only if the user pushes the [1] key will the controller erase the flash. Since erasing the flash memory is slow (several seconds), the controller will inform the user that this is happening by displaying:

**ERASING FLASH #1
PLEASE WAIT 5-6 SECONDS**

or

**ERASING FLASH #2
PLEASE WAIT 5-6 SECONDS**

Caution: erasing flash memory permanently removes all records from that memory!

Selecting to load the flash memory, the controller will first ask which flash memory to load:

**ABORT =0,
LOAD FLASH 1/2 ?**

After selecting a flash memory, the controller displays:

OK to Transmit Data

This same data is sent out the RS-232 port preceded and followed by 2 sets of Carriage Return and Line Feed characters. Then the controller expects to get an ASCII earthquake record from the 9-pin D-Sub RS-232 input. If the data loads ok, the controller will re-display the Service Menu. If an error occurs, the controller will display an error message telling the user that the data had a format error or there is not enough room in the flash memory for the data to be stored.

Selecting to show a flash memory directory results in the controller showing the earthquake record names and sizes, one at a time for a selected memory. The user then gets to select an abort exit or show the next record. If no records exist, the controller will show an error message for empty memory.

Re-Calibrate Function [2]

If for some reason the motor slips on the clutch, the shaking table will need to re-calibrate the relative encoder. This Service Menu option allows this to occur without the need to cycle power on the controller off and on again.

External Input Function [3]

This selection allows the shaking table controller to accept a +/-8 volt (+/-2.5 inches) input displacement command voltage through the external input BNC connector.

2nd Channel Output Function [4]

There is a hidden selection option ([4] key) in the Service Menu. This option allows the user to change what is output from the 2nd D/A channel during earthquake motions. The selection can be either acceleration (normal) or displacement command. The 1st analog output channel is always displacement feedback. This selection is NOT permanent and will revert to acceleration automatically when the controller is turned on again.

System Maintenance

The mechanical system is designed to operate with a minimum of maintenance in a clean, classroom environment. Dusty, dirty or wet conditions will reduce the life of the system and require more cleaning and maintenance. Try to keep the system clean and dust free.

Table guide bearings

The linear bearings are a self-lubricating design. All that is required is to keep the guide shafts clean and free from debris and abrasive materials. This is best accomplished by wiping the exposed shafting with a clean cloth dampened with a light machine oil, such as 3-in-1 oil.

Note: Do not use WD-40, Teflon™ (PTFE) sprays or lubricants, or silicon oils or sprays. Do not lubricate the bearings too often. They are self-lubricated and an occasional cleaning with light oil is all that is required.

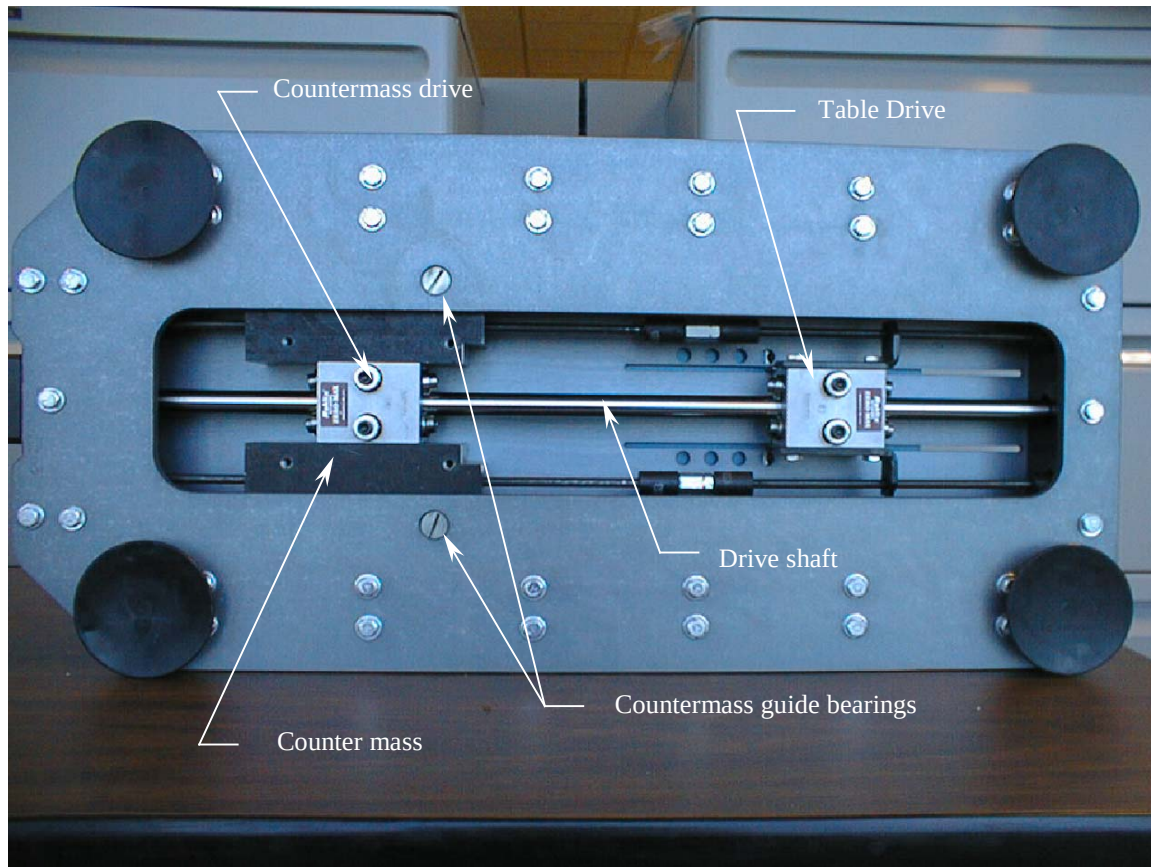
Cleaning and lubrication the guide bearings:

With the power disconnected, the table can be pushed by hand with some effort. Push to one end and wipe down the exposed guide shafting. Push the table to the other end and wipe down the newly exposed shafting.



Guide bearing rail cleaning and lubrication

Drive Mechanism



Drive shaft

The earthquake system is driven by a servo motor through a unique drive mechanism called a Roh'lix™ drive.



This is a friction drive that acts as a threadless lead screw, with helically arranged rollers contacting the spinning drive shaft. There are actually two drive units, a right hand drive for the table and a left hand drive for the counter mass. These friction drives can creep or slip slightly during operation. That is why the system needs to be homed, driving the table and mass to the end stops, before operation.

For smooth and reliable operation, it is necessary for the shaft to be clean and dry. Depending on the operating environment, contaminants can accumulate on the shaft, resulting in slipping or rough operation.

Cleaning the drive shaft

Warning! To access the drive shaft it is necessary to flip the table assembly over. This exposes dangerous pinch points. Make certain that electrical power is disconnected before exposing the bottom of the system.

Remove power from the system and flip the table on its side or top. Moisten a clean cloth with 3M Desk and Office Cleaner or isopropyl alcohol, and wipe the shaft surface. Do not apply any liquid directly to the mechanism. It will be necessary to rotate the shaft by hand to expose the entire shaft length. Wipe the exposed outer diameter of the friction rollers as well. Repeat as needed to clean the entire assembly. Do not lubricate the drive shaft. Do not clean the drive shaft with water, or harsh chemicals.



Cleaning the drive shaft

Roh'lix drives.

The slip force on these drives is adjusted by tightening the cap screws, which compress the preload springs. These are pre-set at four full turns from loose. There should be no need to adjust this setting. However, if they are ever adjusted, take care to adjust the bolts to even numbers of turns from loose to preserve alignment of the drive.

Counter mass guides

These guides prevent rotation of the counter mass due to drive torque. They are factory adjusted and thread-locked into place. If the counter mass is loose enough to rattle when rotated around the drive shaft, these could be adjusted. Do not over tighten. The bearing material is the same and the table guide bearings, so no WD-40 or silicone spray! . A drop of light oil squirted on these when cleaning the drive shaft will extend their life.

All other bearings are factory lubricated and require no routine maintenance.

Appendix Shaking Table Earthquake Files

The shaking table controller saves and plays back earthquake records from 2 flash memories. Earthquakes can be added to the flash memories as long as space exists. However, the flash memory cannot erase a single selected earthquake record. The entire flash memory has to be erased and then re-loaded with the desired earthquake time histories. The Service Menu from the Main Menu allows you to access the Flash Memories to get directories of the earthquakes stored there, to add another earthquake record, or erase the entire flash memory. The shaking table controller has 2 separate flash memories with 512 Kbytes available in each memory. This is enough space to save about 50 earthquakes total in the controller.

Earthquake records are downloaded to the shaking table controller via a RS-232 connection. The earthquake data is sent in an ASCII format to the controller. The primary data sent is an earthquake name in ASCII followed by a dummy entry for sample rate and then followed by 3 columns of data for displacement, velocity, and acceleration. The shaking table is controlled in displacement; therefore the displacement data is the actual command data for the shaking table. The velocity and acceleration data are NOT mandatory to be present, but they do have to be represented by zeroes. The velocity data is used as a command feed-forward to help the shaking table to respond to the displacement command at higher frequencies. The acceleration data is only present to be output out of the controller's 2nd external D/A converter as a read-out signal only.

Shaking Table Earthquake Preparation

Making Earthquake Record fit the Shaking Table

Before converting an acceleration record for use with the shaking table, the earthquake record must be high-pass filtered to limit the stroke required. Since the shaking table has a full-scale stroke calibration of +/-2.5 inches, most earthquake records will not work directly on the shaking table. In order to accomplish this, the user must provide some means to high-pass filter the desired data. An .m file for Matlab can be supplied free-of-charge from MTS that will assist a user in pre-processing an earthquake record. The file: quake.m can be run on any Matlab system version 5 or higher and will provide the means to filter and re-sample the data to the proper sample rate.

All earthquake records for the shaking table MUST use a sample rate of 10 milliseconds (0.01 seconds). The earthquake data is loaded into the shaking table controller in ASCII via a RS-232 link with the following parameters:

Baud Rate	9600 Baud
# Data Bits	8
Parity	NONE
# Start Bits	1
Flow Control	NONE

The format of the data sent is as follows:

1st Line: Up to 24 Character description of the earthquake, followed by the minimum of an ASCII Carriage Return. ASCII Line Feed, Space, and Tab characters are permitted and are ignored by the input process no matter where they are encountered. Blank lines, however, are NOT permitted.

2nd Line: ALWAYS contains the ASCII characters: E800<CR>

This is the file sample rate in hexadecimal as a rollover counter for the internal microprocessor – should NEVER be changed.

3rd Line and onward:

Three (3) 4-digit hexadecimal numbers separated by ASCII Spaces or Tabs represent each earthquake data sample. The first number represents the displacement, the second, the velocity, and the last is the acceleration for this data point. Each hexadecimal number MUST have 4 digits; therefore, the number zero is represented by “0000”. Each number is scaled so that 7FFF Hexadecimal (32,767 decimal) is equal to 2.5 inches, 30 inches/second, or 2 G’s respectively for each column’s full scale. The only limit to the length of the record is the available flash memory to save the data. Because the earthquake record has an arbitrary length, the last data line is ALWAYS a line of 3 hexadecimal FFFF numbers (-1 decimal). Extreme care should be taken in converting the data for this data file so this terminator line does NOT accidentally show up before the end of the data. The Basic program sent with the system (MKQUAKB.ASC), checks for such an occurrence and changes the acceleration number to FFFE (-2 decimal) so the file is not prematurely terminated during download to the shaking table controller.

Look at any of the earthquake records supplied with the shaking table to see examples of the format used for specific earthquakes.