Operations Manual

Cummins Active Noice Control

Sponsor: Cummins Inc.

EML4551

4/9/09

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1 Forward

This manual is intended to provide a means of reproducing the materials, parts, and testing techniques and data of the Cummins Active Noise Control Senior Design Project. More detail about the basics and design of the project can be found in the *Final Design* document associated with this Senior Design Project. However, it is noted that this is a general overview and not a certified operations manual. Always refer to the provided safety and operation manuals for specific equipment used or mentioned in this manual for more comprehensive instructions. Also, due to the hazardous nature of certain testing equipment, use caution and heed any safety instruction provided by product manufacture.

The techniques listed in this manual were chosen due to limitations mainly including existing equipment, equipment availability, and project budget. Other means of replicating preformed tests are available. This manual's intention is to present at the least a method to make a solid comparison for the user.

2 Warnings

Due to the electrical and high magnetic fields of certain materials and testing equipment, safety precaution must be made while operating or handling these objects. Throughout this manual, a yellow lightning bolt, shown below, indicates a safety warning that should be noted prior to proceeding to the next step.

Figure 2-1: Warning Symbol

3 Design Description and Assembly

3.1 Prototype Design

The prototype design consists of seven main parts; the gear housing, gear cover, MFC actuators, Vibrablock perimeter extrusion, sound barrier panel, sound absorbing foam, and the associated bolts and washers. These components, with the exception of the MFC actuators, are essentially a bottom up bolt on assembly. The MFCs require an adhesive for attachment and also wiring due to their electrical needs. Please refer to Figure 3-1 for an exploded diagram of the assembly.

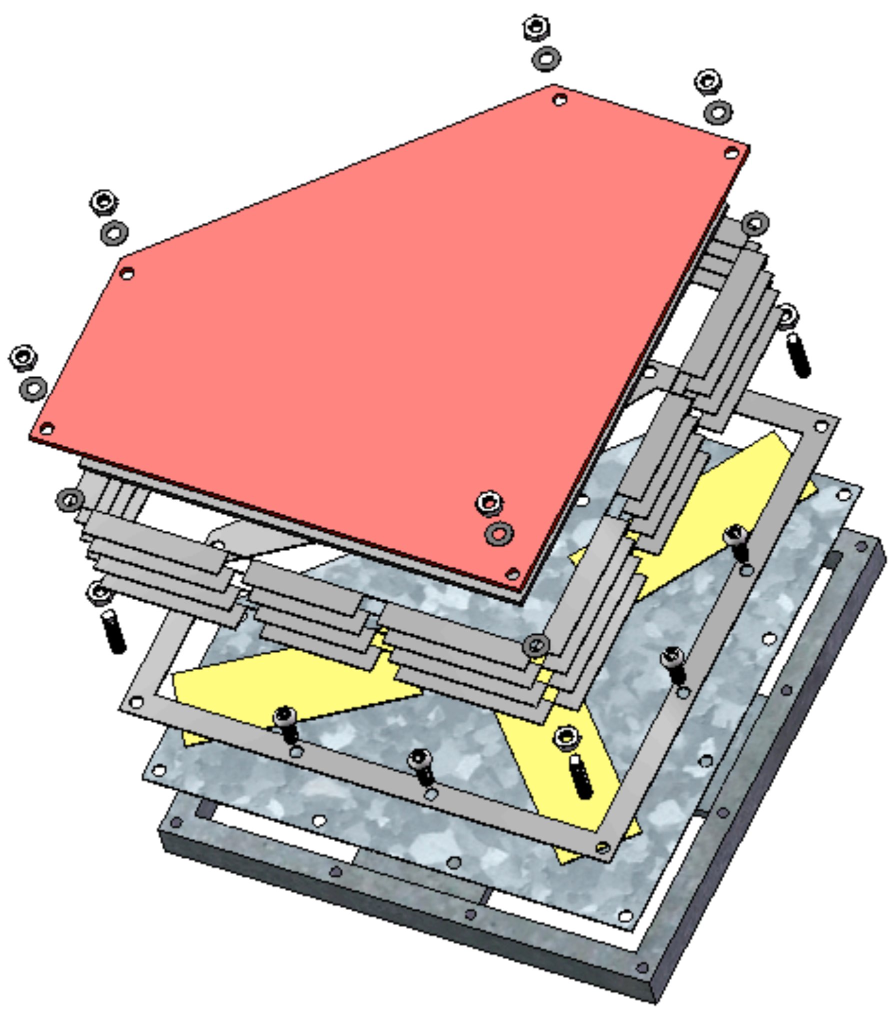


Figure 3-1: Exploded Assembly View

3.2 Assembly Instructions

3.2.1 MFC Wiring and Application

1) Determine the positioning of the MFC actuators. For the mentioned project, the MFCs are oriented in the direction of the propagated vibrations, i.e. towards the center nodal point. Please refer to Figure 3-2 and A1 for clarification.

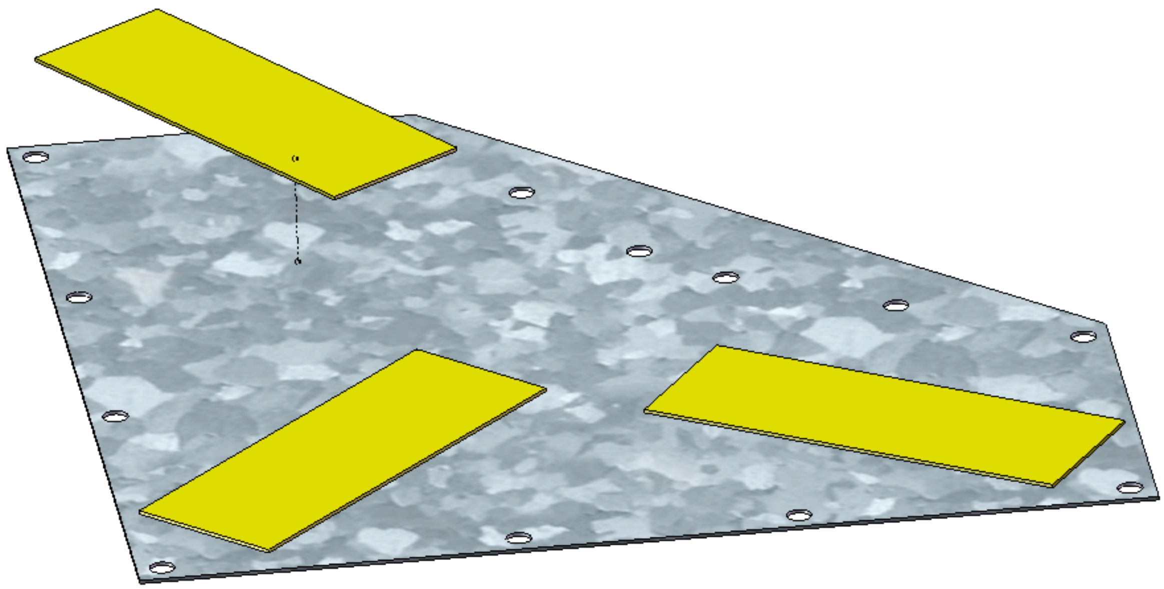


Figure 3-2: MFC orientation on scale model cover

2) Using a graphite or grease pencil and a cardboard cut-out stencil of the MFC, mark the top side of the gear cover for positioning reference. See Figure 3-3.

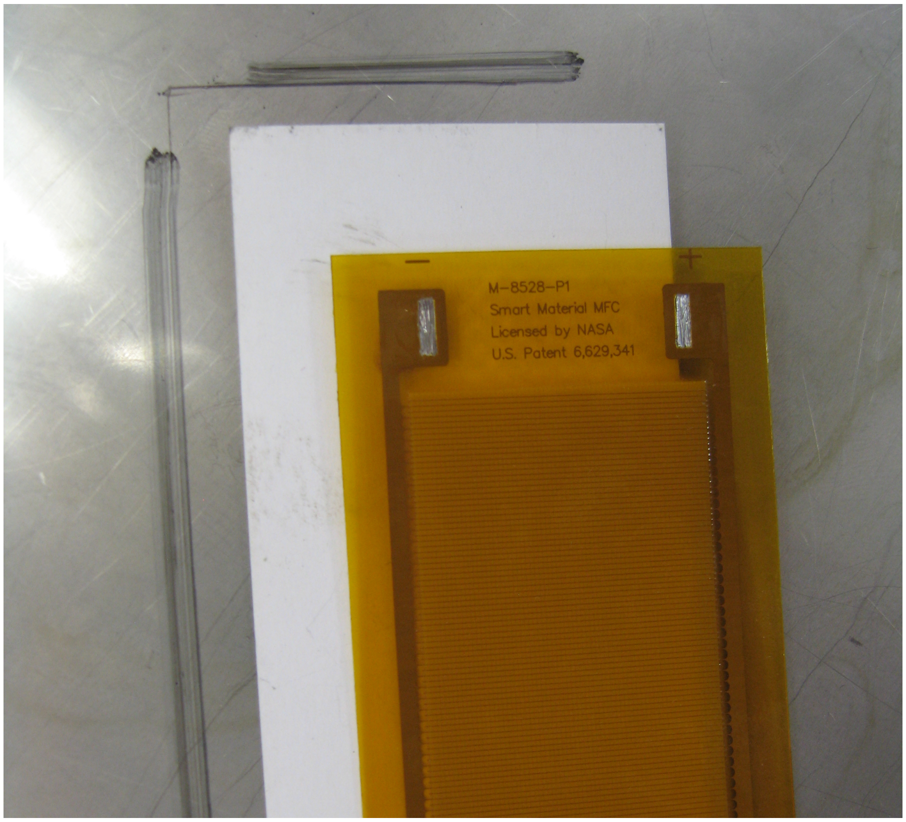


Figure 3-3: MFC, MFC cutout, and stencil marking

Always use an oven glove or some type of heat rated hand protection when using a heat oven or the like.

3) Pre-heat a heat oven or vacuum oven to 50°C to 60°C, if available. Using a heat oven is not necessary, but recommended.

When using strong adhesives, it is recommended to use safety gloves.

4) Apply adhesive, 3M DP 460, sparingly to the underside of the MFC using applicator gun and mixing nozzle.
5) Press MFC upon the gear cover, positioning it inside the reference lines.
6) Apply moderate force to the MFC to squeeze the adhesive from the inside out heeding caution to air bubbles.

7) Wipe excess adhesive away using cotton swabs.

8) Repeat Steps 4) - 7) for remaining MFC patch actuators.

9) Carefully place gear cover inside heat oven.

10) Place small weights on top of each patch actuator being careful to avoid touching excess adhesive.

11) The MFCs have the tendency to shift for the first 10-20 minutes, so pay close attention to the patch actuators' orientation and re-position if necessary.

12) Let MFC actuators cure inside the heat oven for two hours.

13) Remove gear cover from heat oven and allow to cool for at least half an hour.

14) Begin wiring the MFC actuators by pre-cutting black and red 16 awg wire to lengths of about three feet. See Figure 3-4.

Figure 3-4: Red and black 16 awg wire and wire stripping tool

15) Using a wire stripper, strip the ends of each piece of wire.

16) Match the black wires with the negative contact areas and the red wires to the positive contact areas. See Figure 3-5.

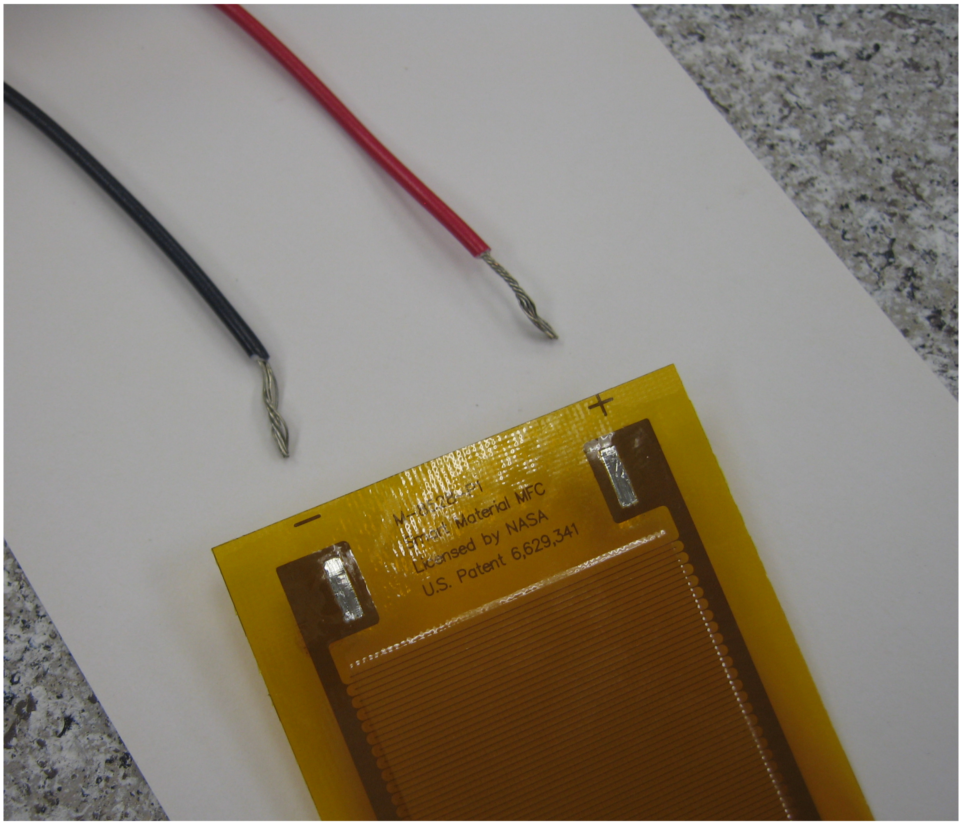


Figure 3-5: MFC positive and negative contact patches

17) Using soldering flux and soldering iron, solder the bare wire end to the bare contact area on the MFC.

18) Position and organize the wires neatly out of the way.

20) Use same process of applying the MFCs for structures such as the cantilever beam.

3.2.2 Model Assembly

1) If assembling scale model with MFC patch actuators, follow section 3.2.1 to apply MFCs prior to proceeding to the next step. See Figure 3-2.
2) Cut Vibrablock to go around the perimeter of the scale model cover; it should be about half an inch wide all around.
3) Using a ¼" hole punch or drill fitted with a ¼" drill bit, punch holes through the vibrablock in the same locations where holes exist on the scale model cover. See A1.
4) Peel back the clear plastic backing to expose adhesive side and place Vibrablock washer layer on top of the scale model cover. See Figure 3-6.

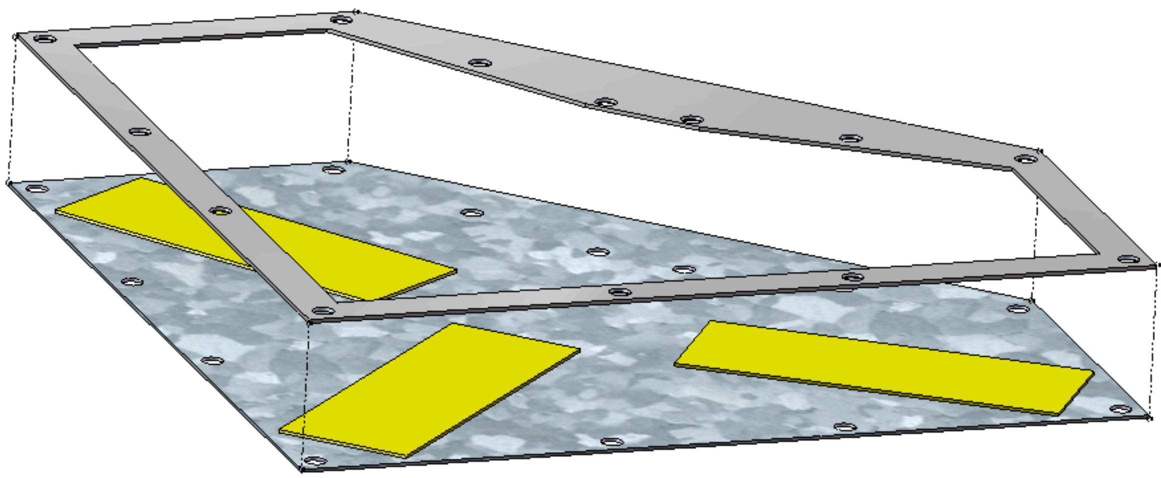


Figure 3-6: Vibrablock washer layer placed on top of cover

5) Place a small bead of RTV sealant along the top of the scale model housing. See Figure 3-7.

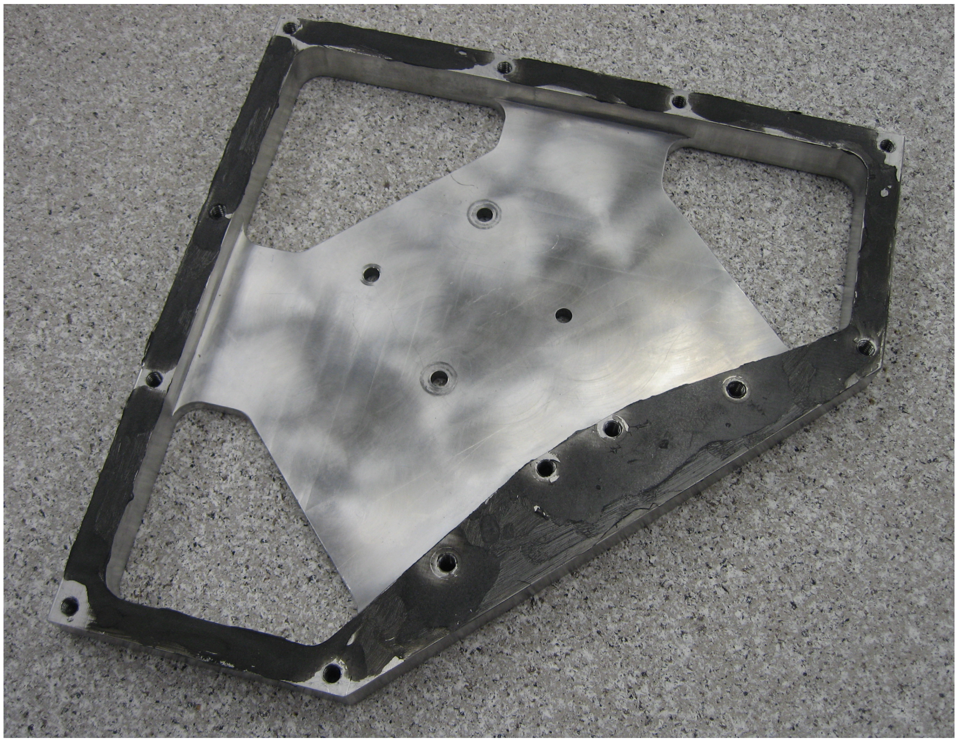


Figure 3-7: Scale model housing with black RTV sealant

6) Before the RTV dries, place the bottom of the scale model cover on top of the scale model housing. See Figure 3-8.

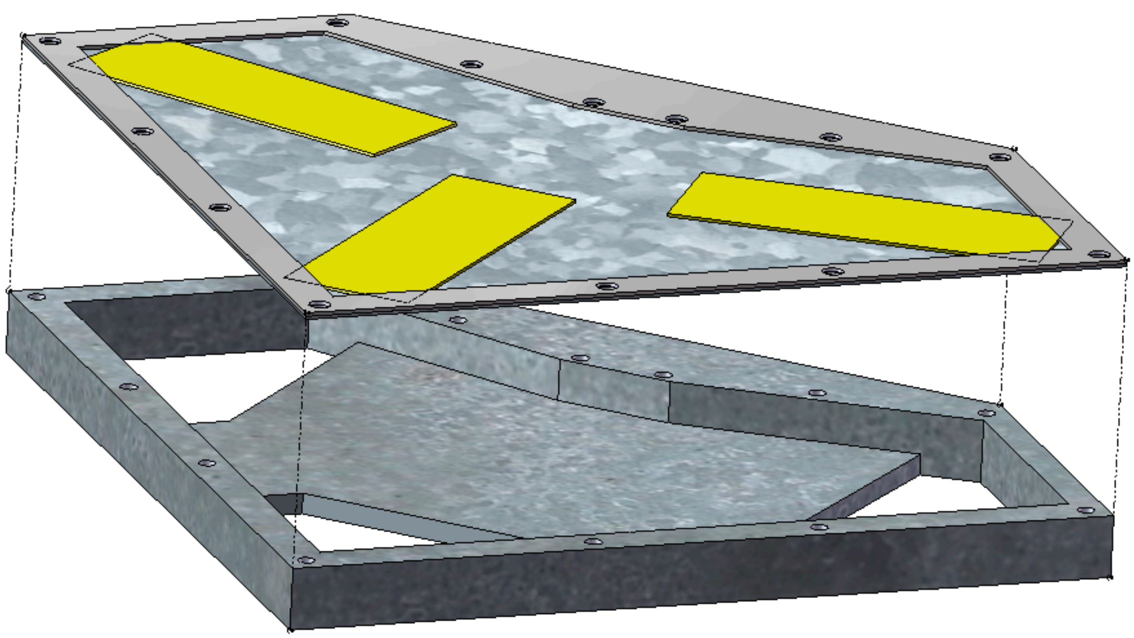


Figure 3-8: Scale modeling cover positioned above scale model housing

7) Using ¼”-20 button head socket cap screws, screw down the scale model cover to the housing; make sure to only use eight of these screws in the correct inside hole locations. See Figure 3-9 and Figure 3-10.

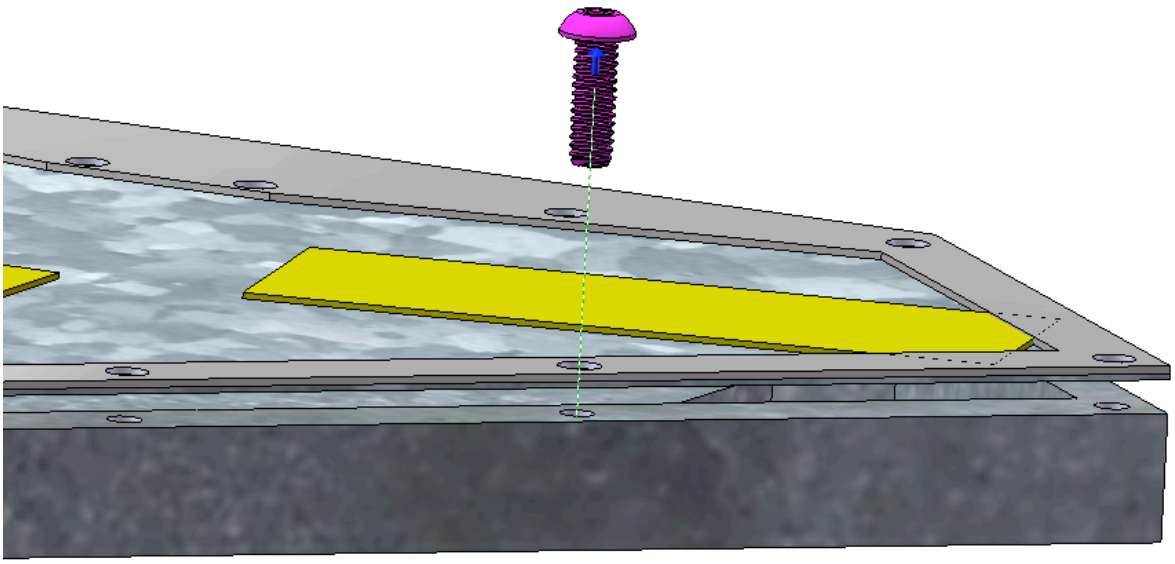


Figure 3-9: Alignment of screw with cover and housing.

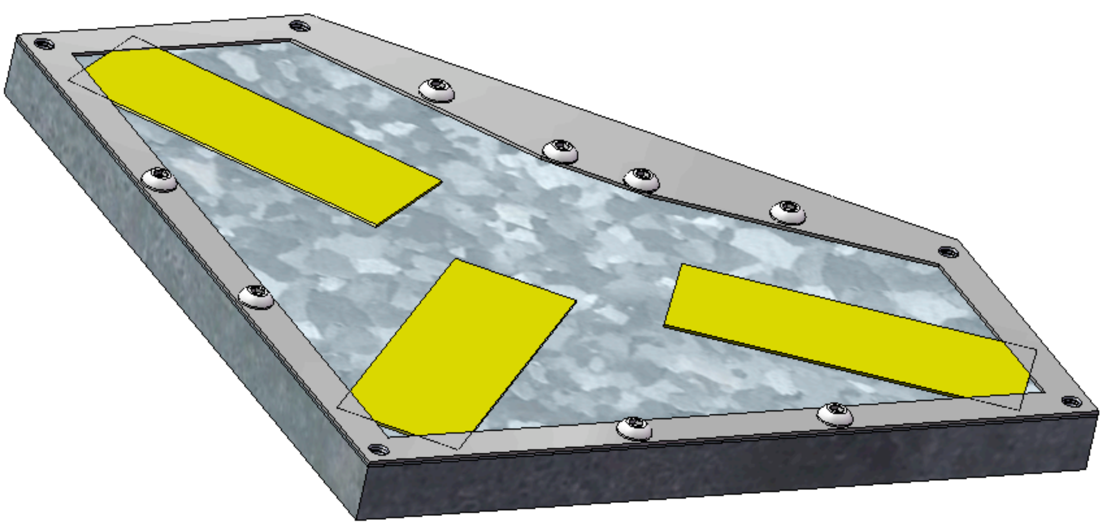


Figure 3-10: Correct locations for button head screws.

8) Cut additional layers of Vibrablock like in step 2) but also cut notches at the 13 hole locations for head clearance; four layers are needed for button head screws.

9) Peel off protective backing from Vibrablock and stack each layer on top of each other, placing the first on top of the Vibrablock washer layer in step 4). See Figure 3-11.

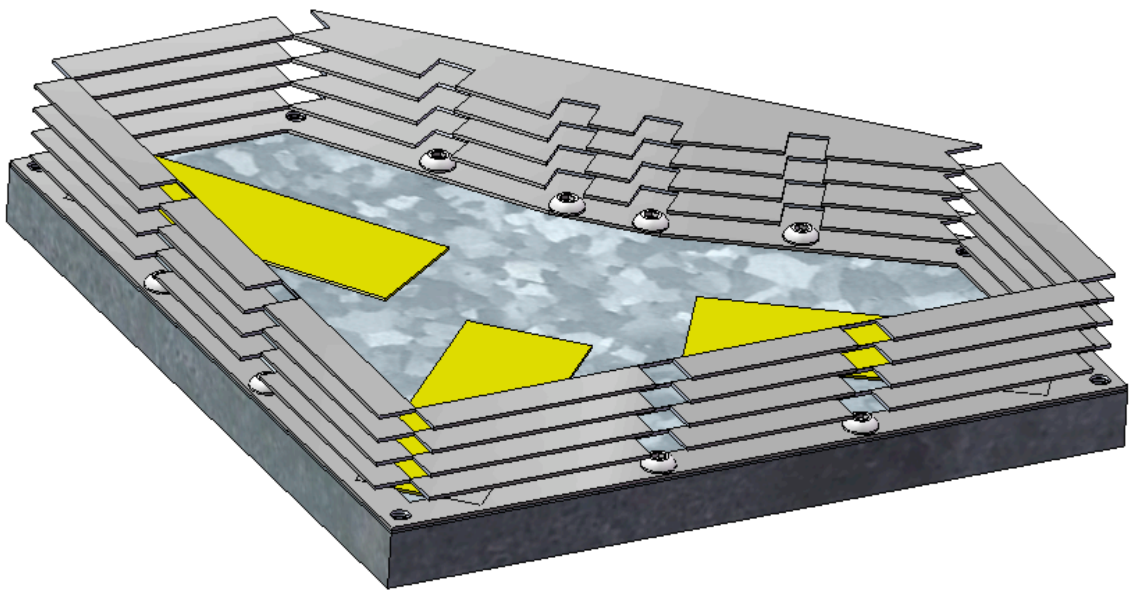


Figure 3-11: Four layers of Vibrablock stacked on top of each other.

10) Screw down the five “keyed” ¼”-20 threaded rod links into the outside corner holes about ½”. See Figure 3-12 and Figure 3-13.

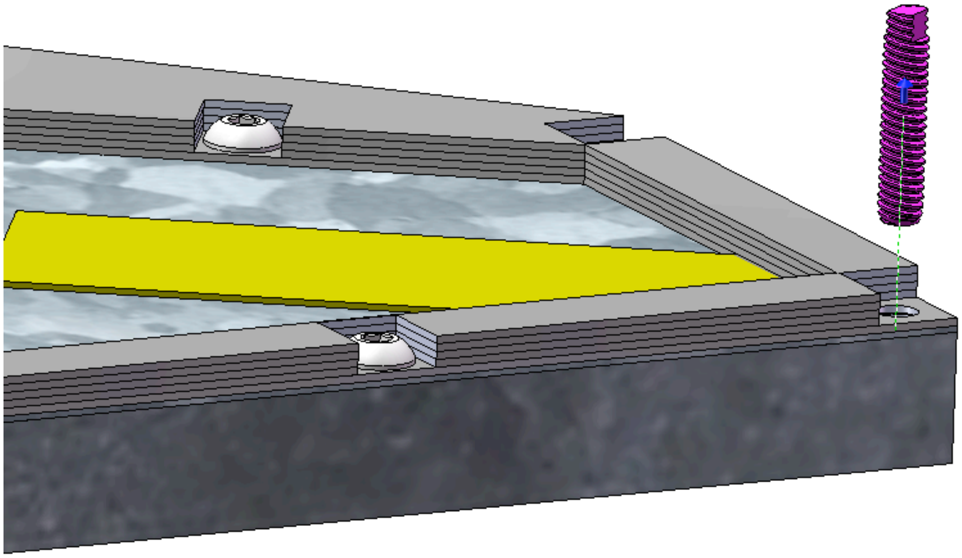


Figure 3-12: Insertion of keyed ¼”-20 threaded links.

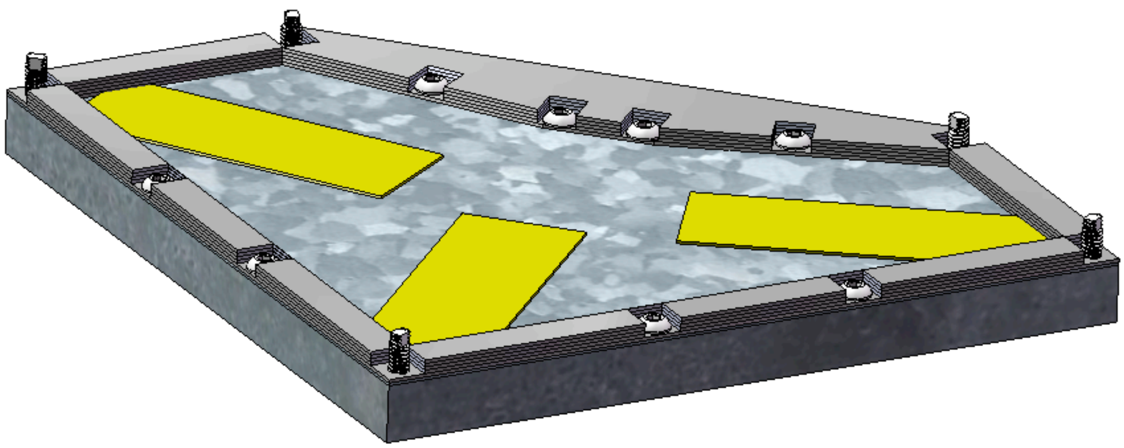


Figure 3-13: Five outside corner locations for threaded links.

11) Screw a ¼”-20 nut down on top of the five threaded links from step 10) tightly. See Figure 3-14.

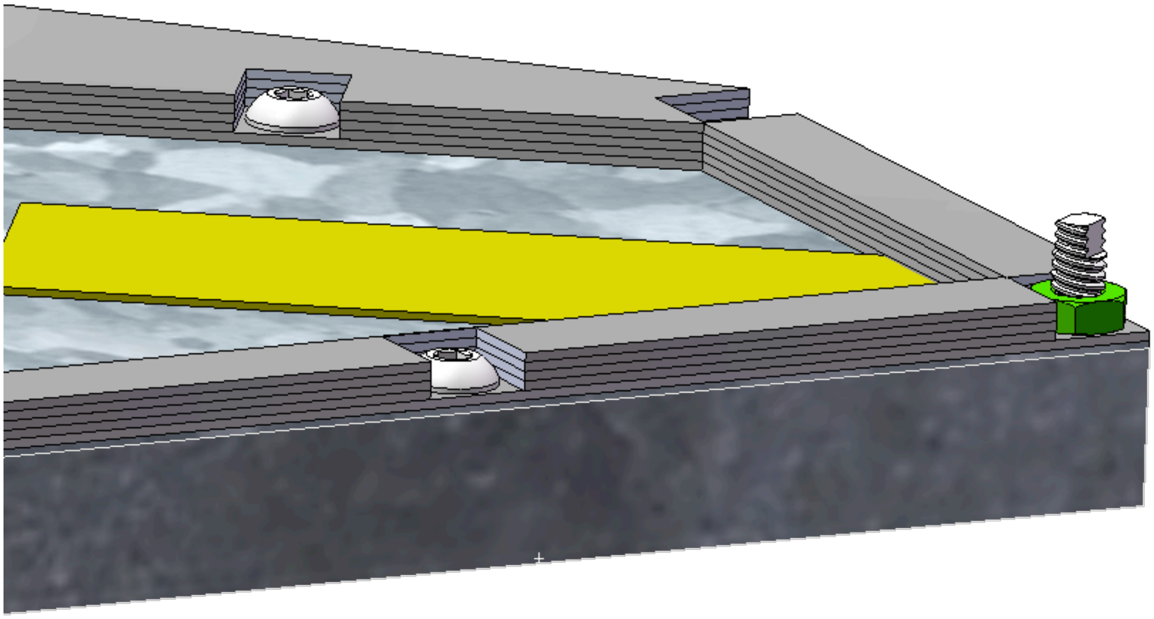


Figure 3-14: ¼”-20 nut placement.

12) Place a ¼” ID rubber washer on top of each of the nuts from step 13). See Figure 3-15.

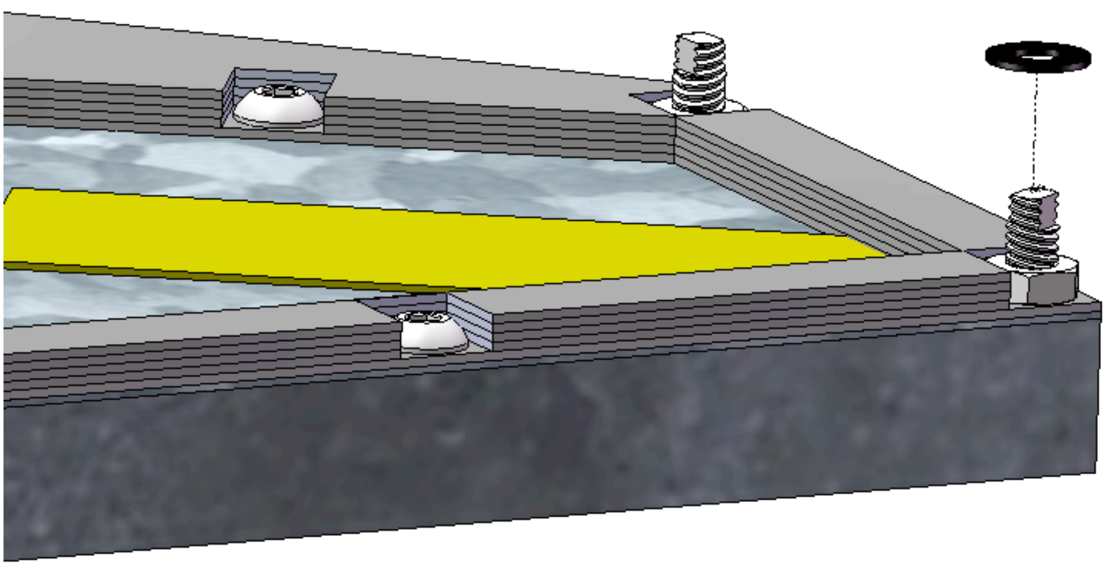


Figure 3-15: Rubber washer placement.

13) Cut a piece of sound absorbent foam to fit the area inside of the cover; the foam layer can be cut small to maintain clearance. See A1.

14) Peel the clear plastic backing off the sound foam and attach to the center of the bottom of the fiberglass sound barrier panel; add layers if space is available. See Figure 3-16.

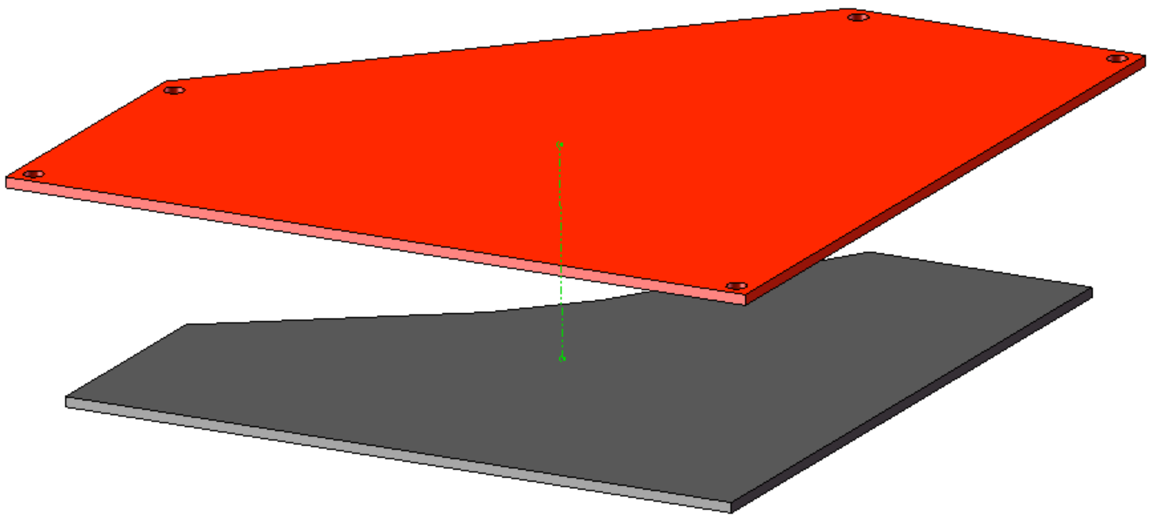


Figure 3-16: Sound absorbent foam place underneath barrier panel.

15) Place the sound barrier panel on top of the assembled parts from earlier, aligning it to the five outside corner threaded links. See Figure 3-17.

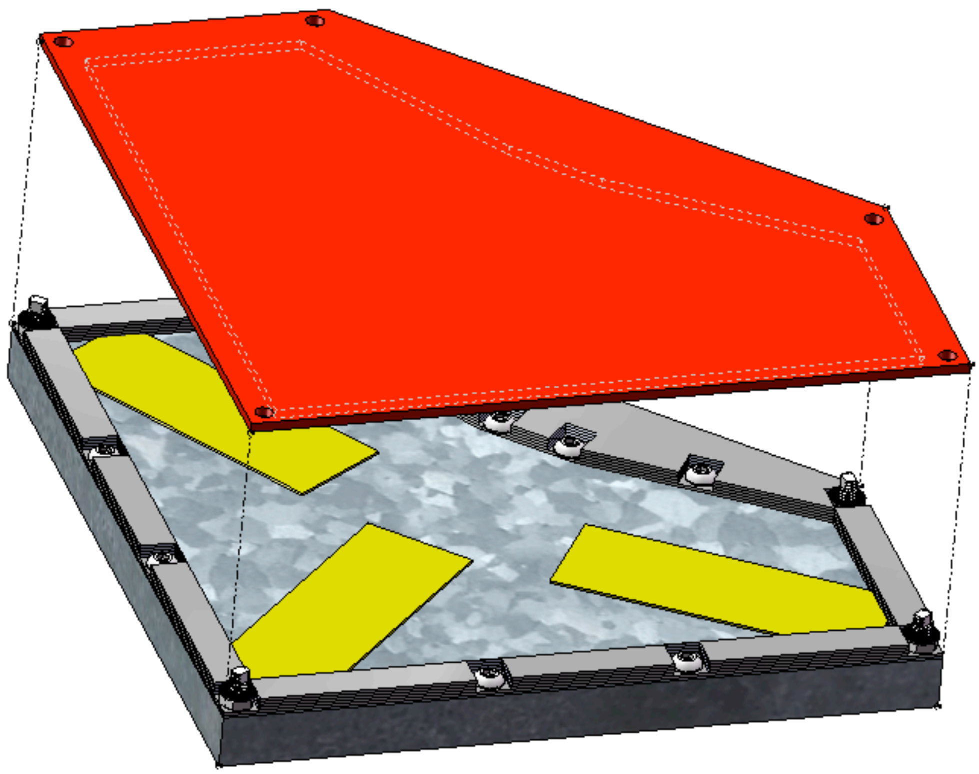


Figure 3-17: Sound barrier panel located on top of prior assembly

16) Place five more ¼” ID rubber washers on the threaded links. See Figure 3-18.

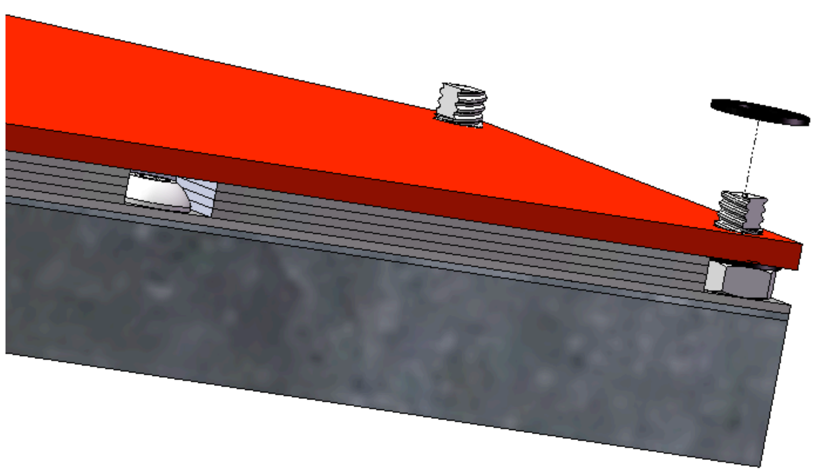


Figure 3-18: ¼” ID rubber washer placed on threaded link.

17) Screw five more ¼”-20 nuts on top of the rubber washers from step 16) to a tight fit. See Figure 3-19 and Figure -20.

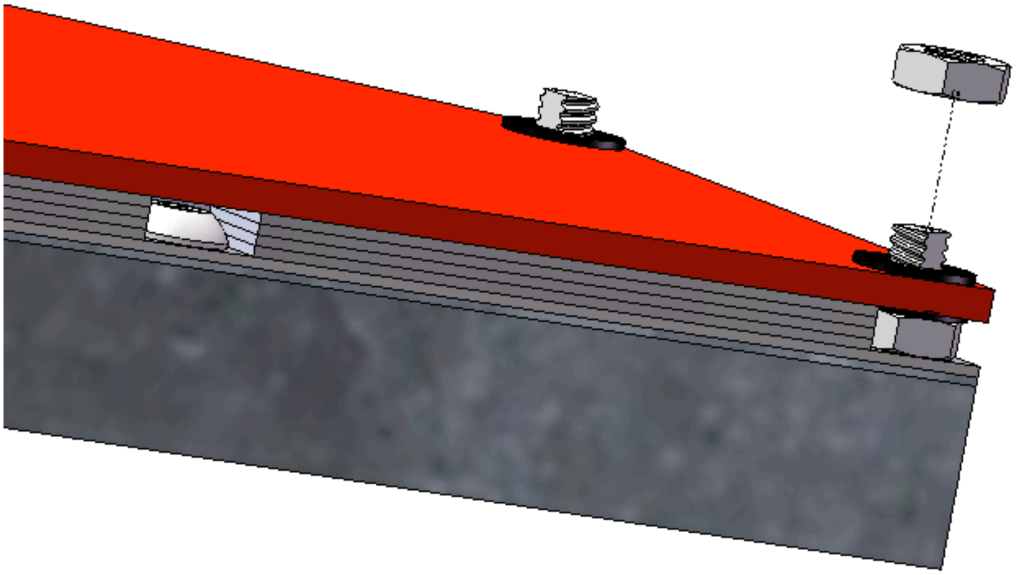


Figure 3-19: ¼”-20 nut locations.

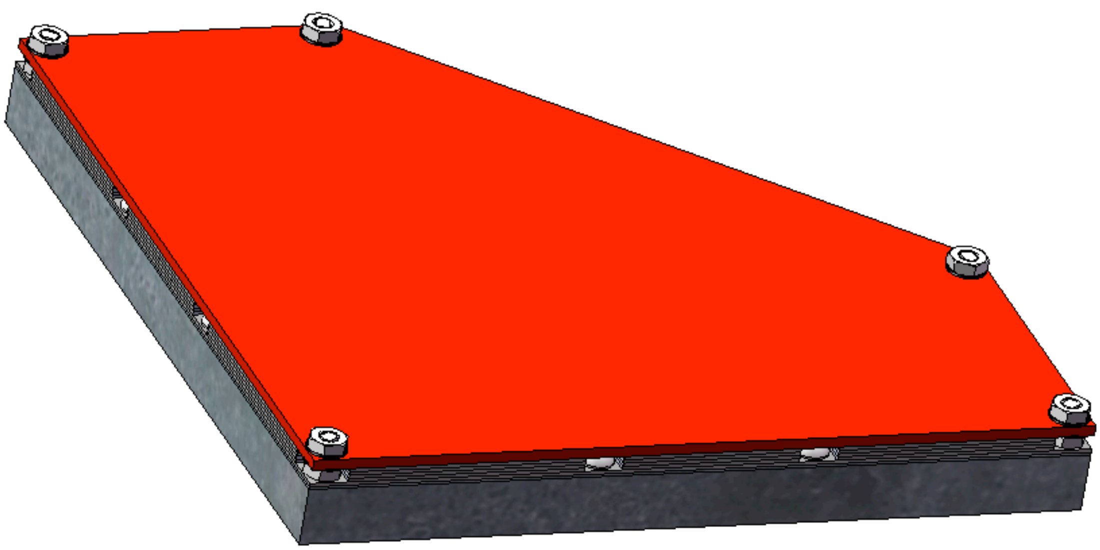


Figure 3-20: Final assembly viewed from the top.

4 Software and Hardware Interface Instructions

4.1 Data Physics Signal Force Shaker Table

4.1.1 Hardware Setup

Abacus (Data Acquisition Computer) (Data Physics DP700 Abacus Lite):

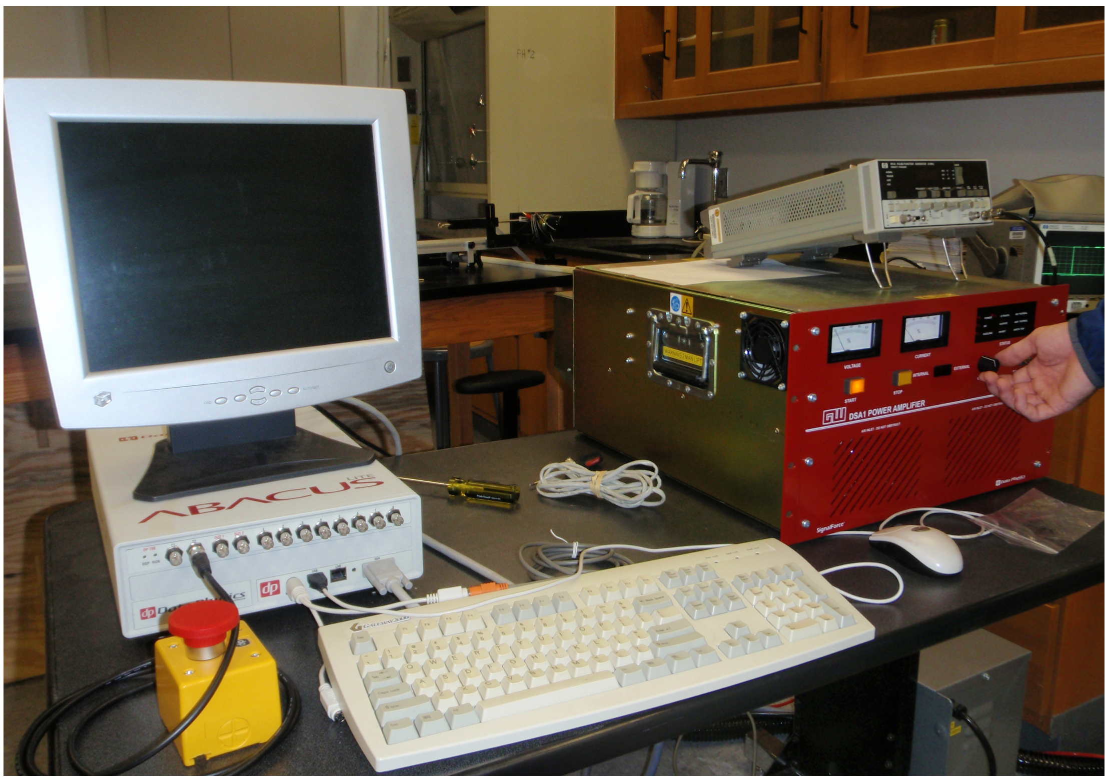


Figure 4-1: Abacus data acquisition system

1) Flip the I/O switch in the back to the " I " position.
2) The “RED STOP” switch should be plugged into the “T2” BNC port on the Abacus.
3) Plug monitor into the VGA port on the Abacus.
4) The mouse plugs into one of the USB ports.
5) The keyboard plugs into the serial port in the front (located to the left of the USB ports).

Amplifier (DSA1 Power Amplifier from Data Physics, part of the Signal Force system):

1) Make sure the "Gain" knob on the amplifier is turned fully counter clockwise.
2) The black switch marked “INTERNAL/EXTERNAL” should be flipped to the internal side.
3) Located on the back of the amplifier is a jack labeled "SIGNAL INPUT"; connect a T-adapter F/M/F BNC adapter to this jack.
4) From the BNC adapter in step 3), run one wire from the adapter to channel 1 on the Abacus machine, and the other port on the adapter is run into the “OUT 1” port on the Abacus machine; this sets the machine up to run in a closed loop mode.

Sound Level Meter (Extech 407730):

Figure 4-2: Extech sound level meter

1) Connect a BNC to RCA adapter to a RCA to 2.5mm adapter.
2) Secure the meter at least 6-10 inches above the shaker table
3) Run a BNC cable from the adapters on the sound level meter to channel 2 on the Abacus.

Shaker Table (Data Physics Signal Force Unit):

Figure 4-3: V300 Mechanical Shaker

1) Attach object to be tested onto the shaker table using M9 screws; four M9's were used to attach both the project's scale model and the cantilever beam.
2) Turn the amplifier unit to the ON position using the key.
3) Check the air inlets and make sure nothing is obstructing them and that the fans are on.
4) Once the "POWER DC" and "COOLING" lights illuminate, push the opaque "START" button in and hold for 5 seconds; the start button should stay lit.

One the power is turned on, the field becomes energized and the shaker becomes a powerful magnet. Care should be taken to ensure that magnetic materials cannot come into contact with the coil or annular gap.

5) Notice the ILS lights on the bottom left side of the shaker table. They are labeled "HIGH", "NULL" and "LOW". The "NULL" light must be lit green. If it is reading "LOW", add pressure to the "ISOLATION" port using an air pump. If it is in the "HIGH" position, bleed pressure from the "ISOLATION" port.

4.1.2 Software Setup (Signal Star)

Before any test begins, hearing protection must be worn by any person in the vicinity of the shaker due to the generation of high noise levels.

Amplifier Pre-Setup:

1) The amplifier should be in the "ON" position with the "GAIN" knob turned fully counter clockwise and the switch on the "INTERNAL" side.
2) Turn "GAIN" knob until the Current is about 16%.
3) Switch to "EXTERNAL"; the shaker table should NOT be moving at this time and the Current should drop back down to 0%.

Signal Star Software Setup (how to run a "Sine" test):

1) Click the icon on the Desktop labeled "SignalStar Scalar"; it will open up and connect to the Abacus. See Figure 4-4.

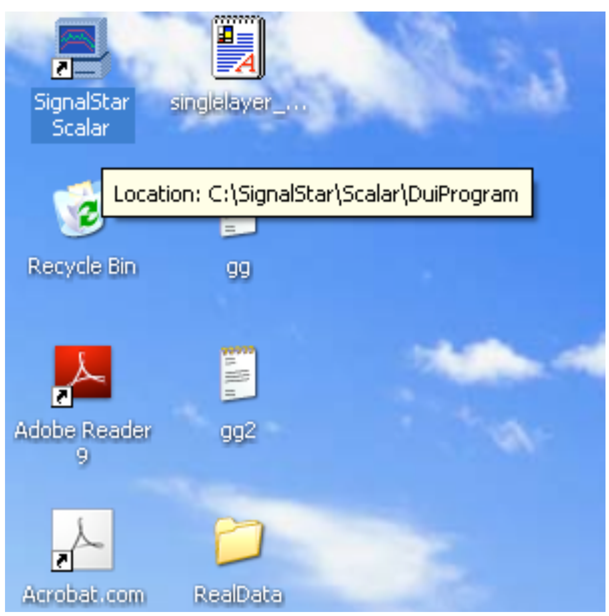


Figure 4-4: Screenshot of application icon

2) Click the white piece of paper to open up a new test.

3) Select “SINE” and click “NEW”. See Figure 4-5.

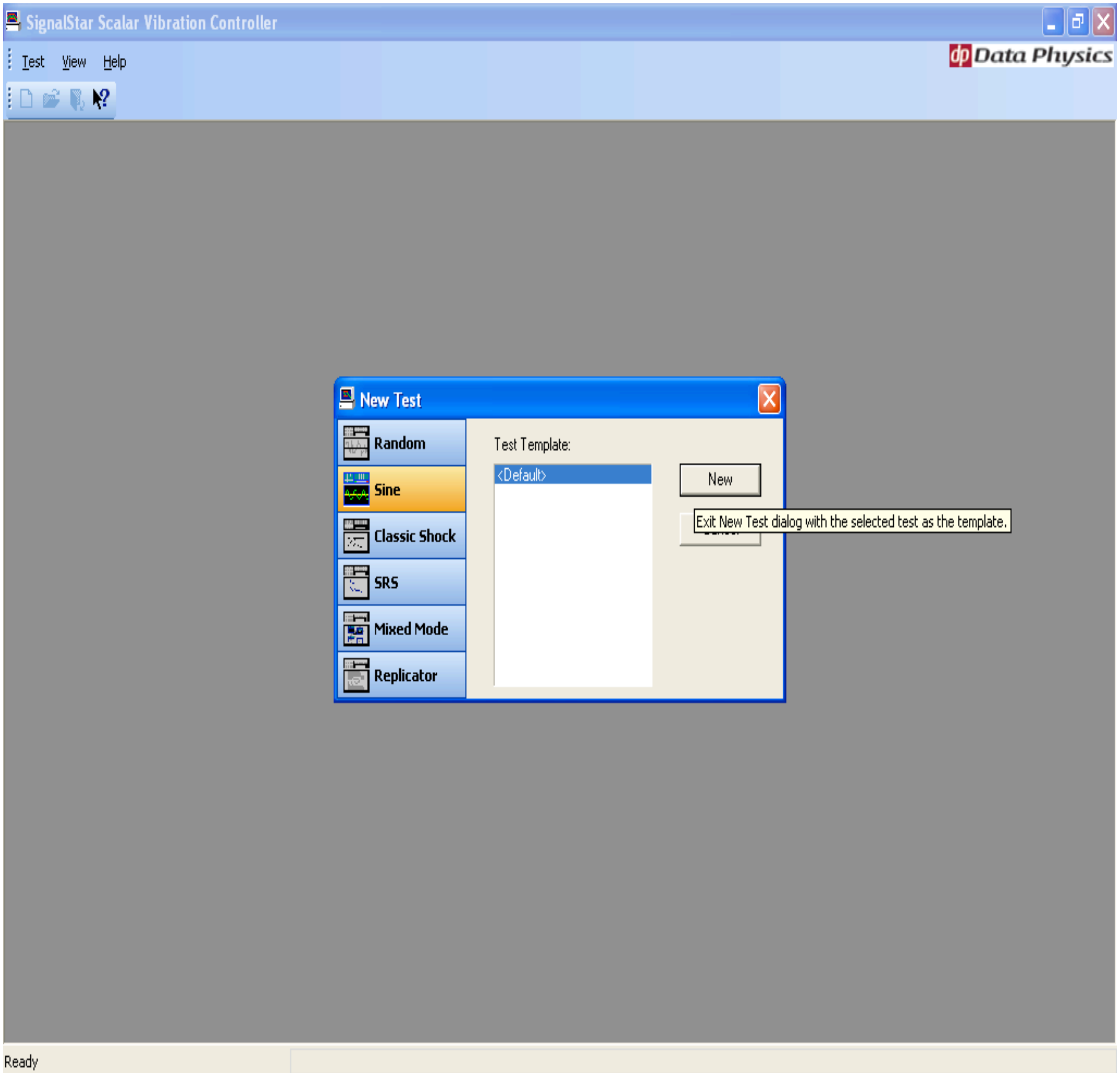


Figure 4-5: Screenshot for starting a new test

4) Name your test.

5) Click the computer icon labeled "TEST SETUP"; this window will remain open for all the tabs mentioned in steps 6) through 15). See Figure 4-6.

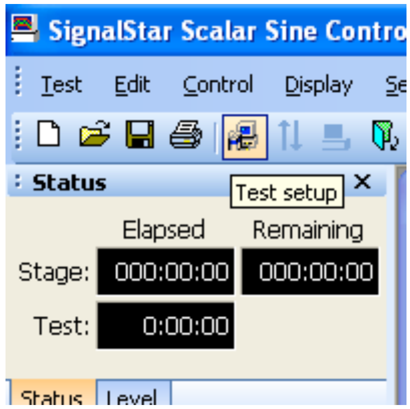


Figure 4-6: Screenshot of the "Test Setup" icon

6) Under the TEST tab set the units as follows:

Displacement: CM

Velocity: CM/S

Acceleration: G

See Figure 4-7.

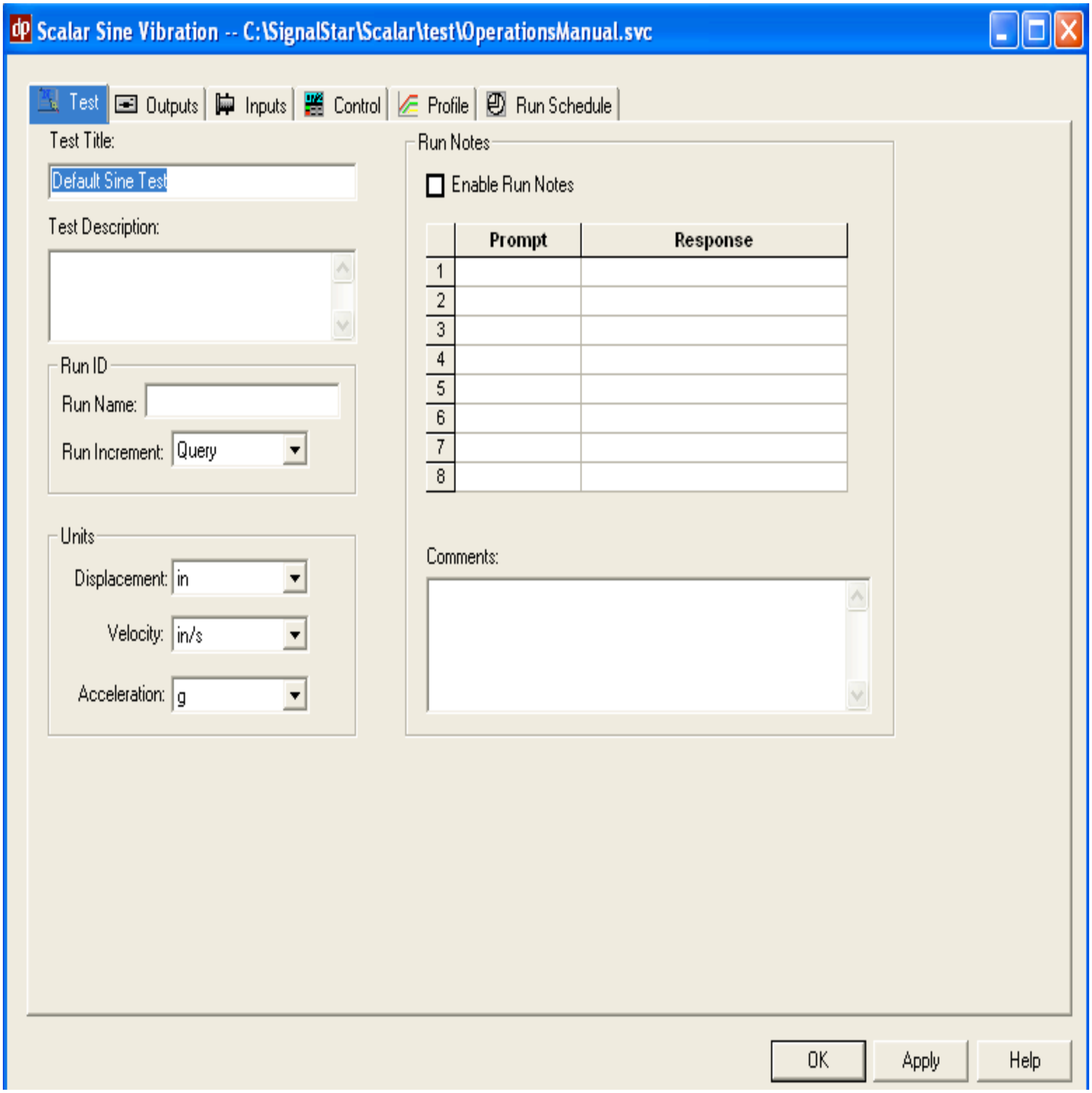


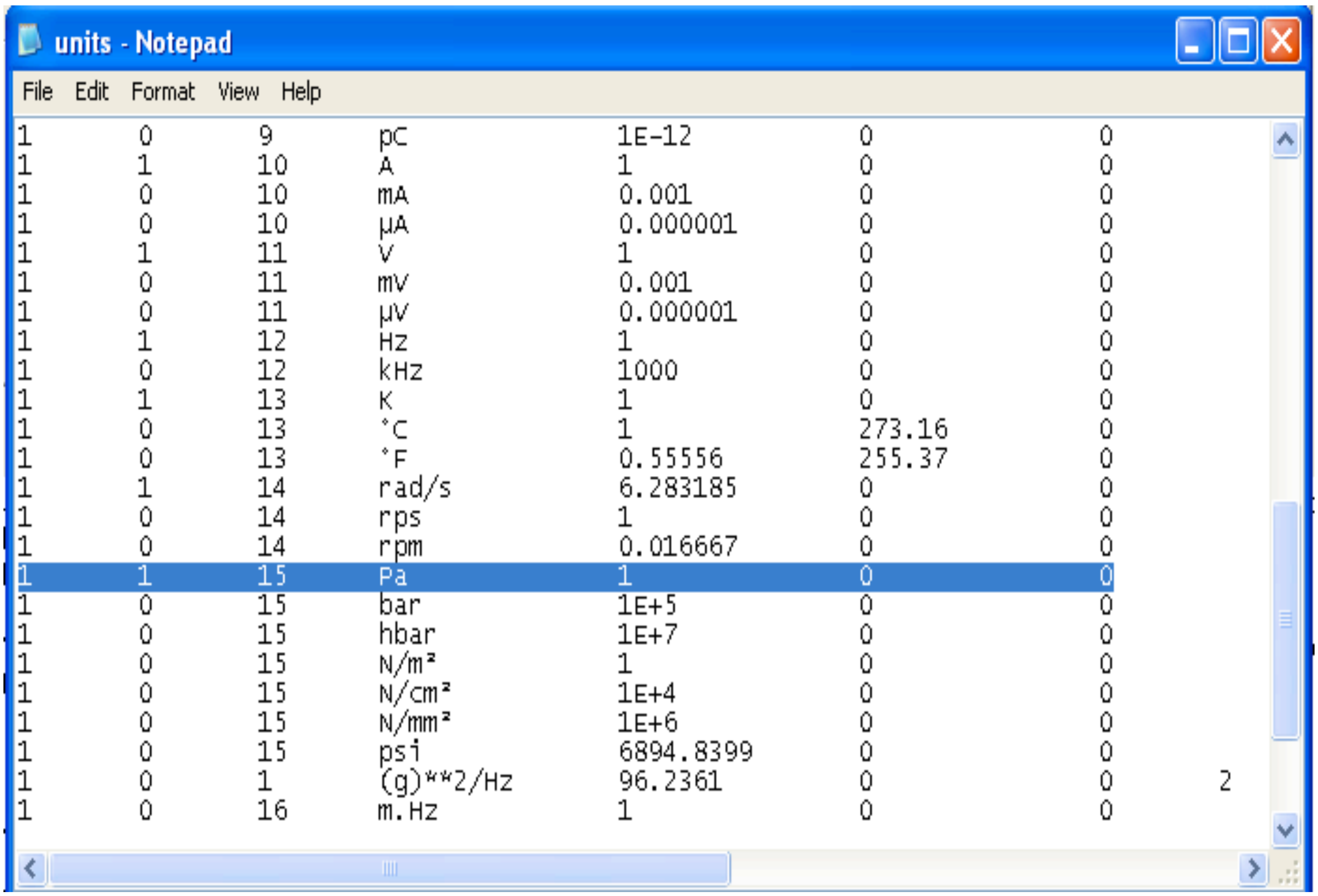
Figure 4-7: Screenshot of the Test Setup menu

7) Under the “OUTPUTS” tab the only thing to be seen is the object’s mass properties. “DUT” is the object subjected to the test, and “FIXTURE” is the mass of any apparatus used to attach the object to the shaker such as adapter plates. Everything else in this tab can be left alone.

8) If a sound level meter is being used, a unit designation needs to added into the system

for Pa. Go to C:\SignalStar\Scalar\Units and open the “UNITS.TXT”. In this file, add the following line at the bottom of the text file in an empty row. After the line has been placed in the text file, save it and exit that folder. See Figure 4-8.

!Prot	Default	Type	Label	Scale	Offset	DB_coeff
"1	1	15	Pa	1	0	0"



units - Notepad

File Edit Format View Help

1	0	9	pC	1E-12	0	0	
1	1	10	A	1	0	0	
1	0	10	mA	0.001	0	0	
1	0	10	µA	0.000001	0	0	
1	1	11	V	1	0	0	
1	0	11	mV	0.001	0	0	
1	0	11	µV	0.000001	0	0	
1	1	12	Hz	1	0	0	
1	0	12	kHz	1000	0	0	
1	1	13	K	1	0	0	
1	0	13	°C	1	273.16	0	
1	0	13	°F	0.55556	255.37	0	
1	1	14	rad/s	6.283185	0	0	
1	0	14	rps	1	0	0	
1	0	14	rpm	0.016667	0	0	
1	1	15	Pa	1	0	0	
1	0	15	bar	1E+5	0	0	
1	0	15	hbar	1E+7	0	0	
1	0	15	N/m²	1	0	0	
1	0	15	N/cm²	1E+4	0	0	
1	0	15	N/mm²	1E+6	0	0	
1	0	15	psi	6894.8399	0	0	
1	0	1	(g)**2/Hz	96.2361	0	0	2
1	0	16	m.Hz	1	0	0	

Figure 4-9: Screenshot of the “units.txt” file

9) Click the “INPUTS” tab in the Signal Star Scalar “TEST SETUP” window. Make sure only channel 1 and 2 have an X in them. On Channel 1 make sure the “EU” is "g" and “Range EU” is set to “10”. On channel 2 the “EU” should be set to Pa, “Range EU” should be set to “10” and “Coupling” should be set to “DC SE”. See Figure 4-10.

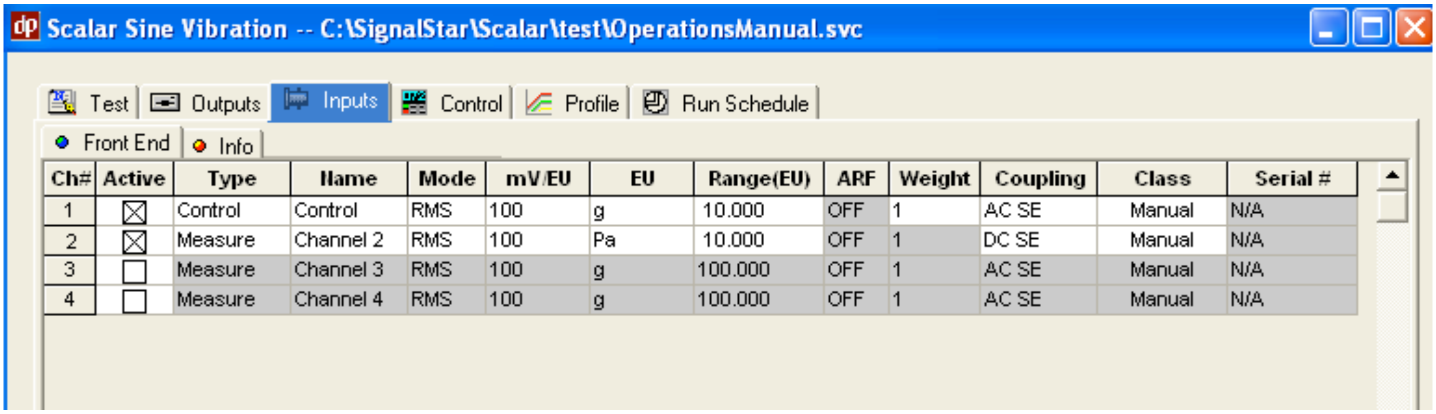


Figure 4-10: Screenshot of the Inputs portion of the Test Setup menu

10) In the “INPUTS” tab click “INFO” and “Direction” on channel 1 to “+Y” and “Direction” on channel 2 to “+Y”. See Figure 4-11.

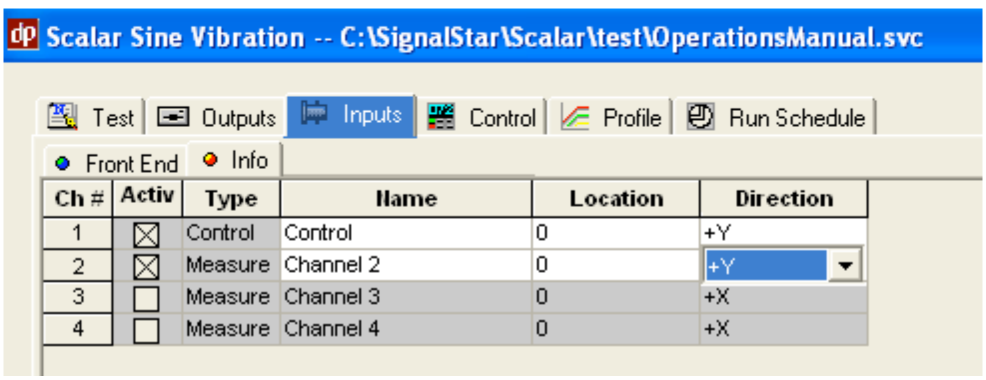


Figure 4-11: Screenshot of the Inputs portion of the Test Setup menu

11) Click the “CONTROL” tab and make the following changes: change the “Sweep Mode” to “Linear (Hz/sec)”, set “Points/Sweep” to “8192”, and set “Meas. Freq. Ratio” to “11” to obtain the maximum sampling rate. See Figure 4-12.

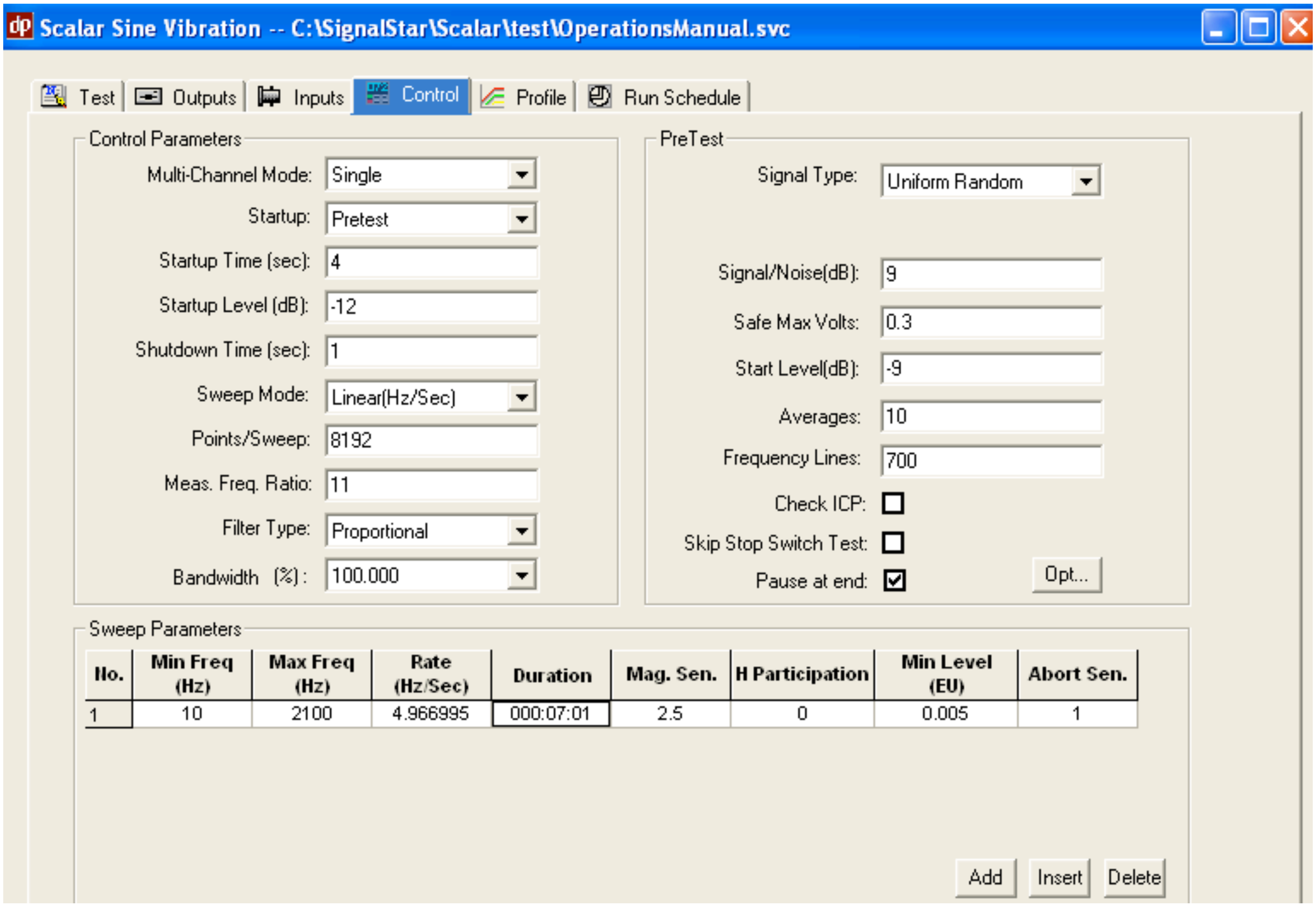


Figure 4-12: Screenshot of the Control portion of the Test Setup menu

12) Go down to the “Sweep Parameters” section in the “CONTROL” tab; set the minimum frequency to nothing lower than 5 Hz or error might occur.

13) Click the “PROFILE” tab; under the Profile section and to the right is all the parameters. Click EDIT and this will show the frequency sweep broken down in three parts: the beginning frequency, a median, and the ending frequency. Altering “Ref” in the 2nd and 3rd rows (median and ending frequency) will determine the ramp up. Do not ramp up to the full amplitude too soon because the test will fail. The amplifier needs time to get up to full amplitude. The actual number is in g's and determines the amplitude the test will run at. 2.5g is the max amplitude the project’s tests were run at. See Figure 4-13 and Figure 4-14.

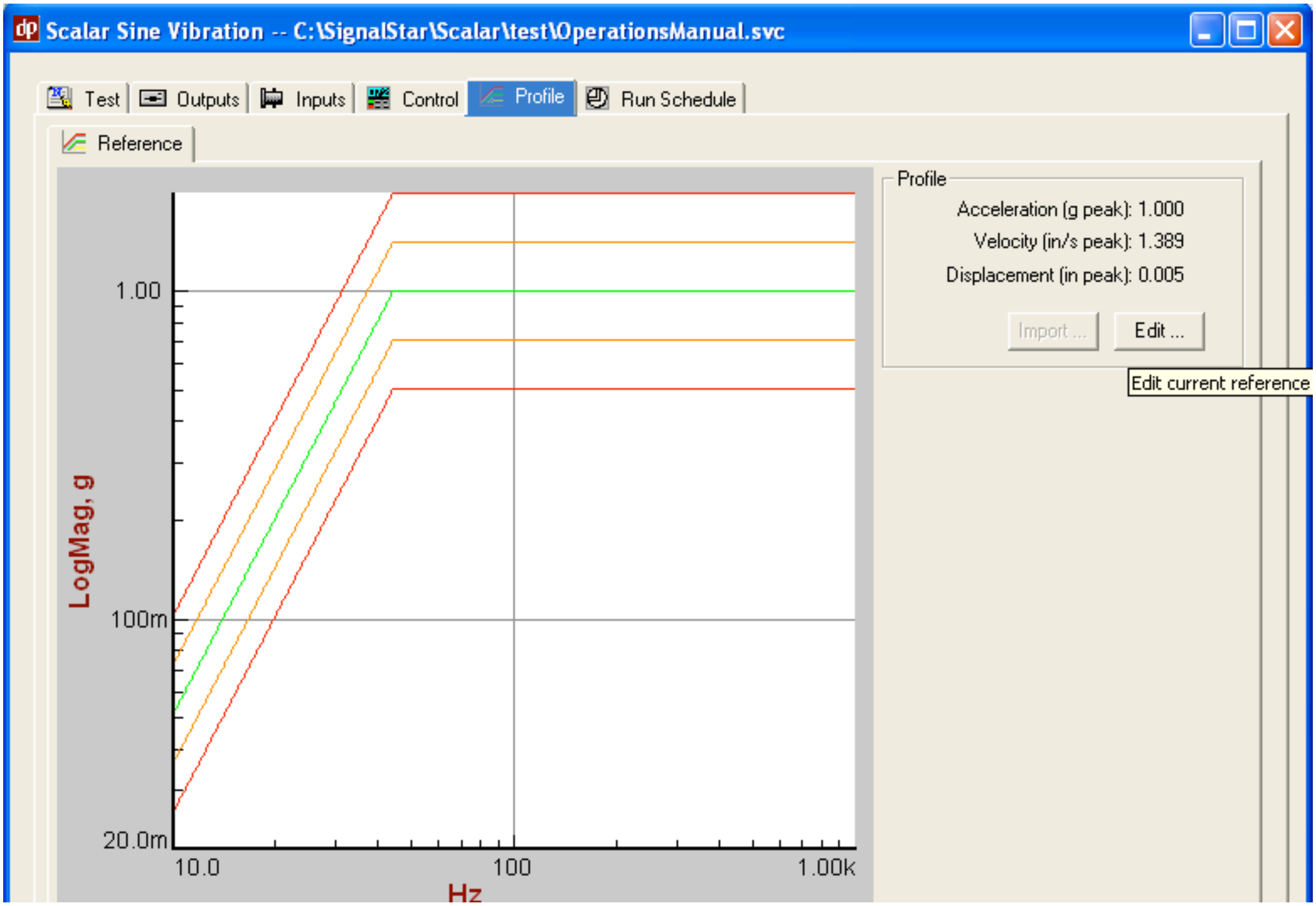


Figure 4-13: Screenshot of the Profile portion of the Test Setup menu

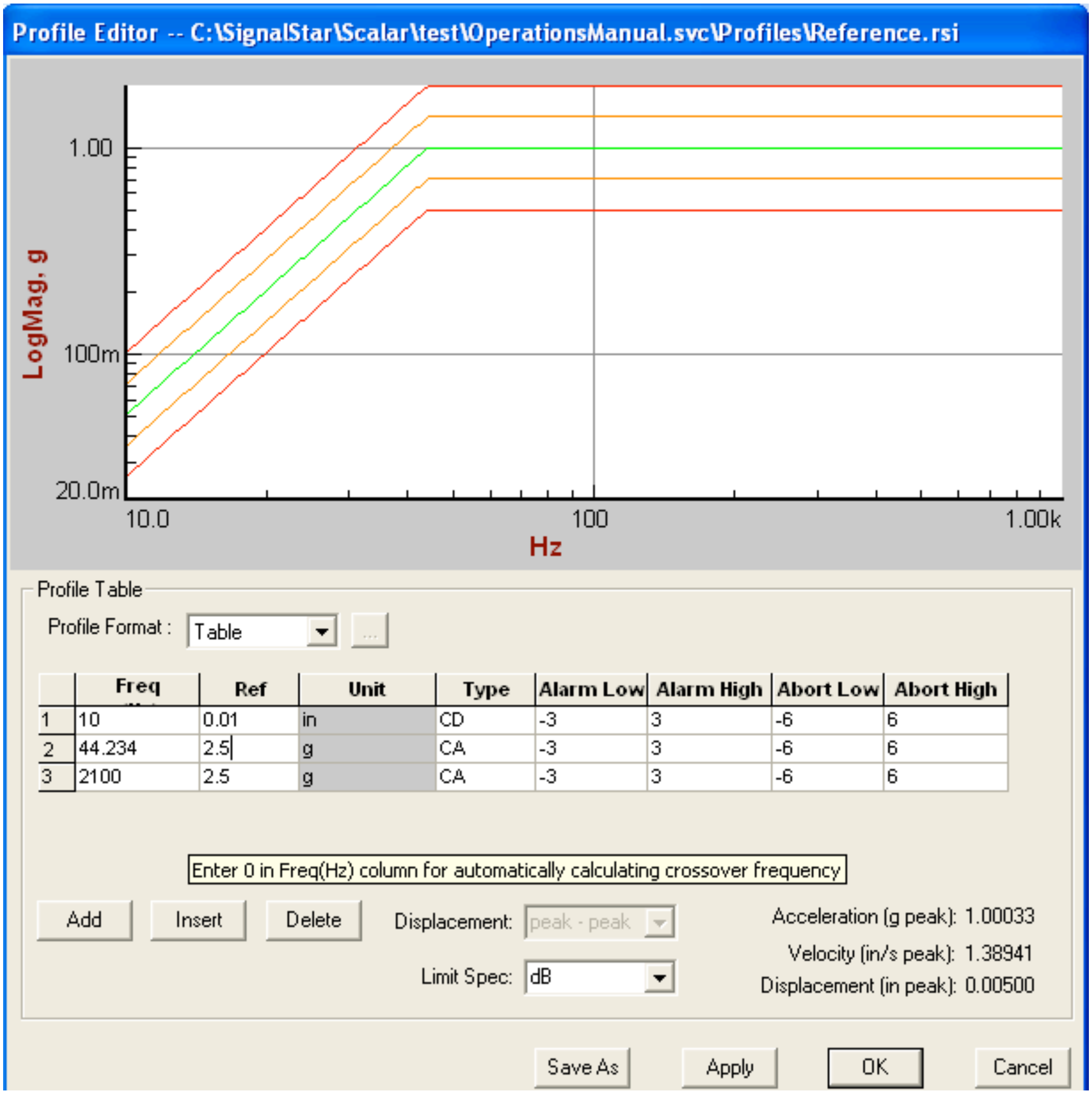


Figure 4-14: Screenshot of the Profile Editor menu

14) Click the "RUN SCHEDULE' tab and setup for either a "SWEEP" or "DWELL" test. A sweep runs a test from the beginning frequency chosen to the ending frequency in steps of 5 hz/sec or whatever the chosen rate is in the "CONTROL" tab. A "DWELL" runs a tests at a magnitude for a specific amount of time at certain frequency. Again choose too low of a frequency, less than 5Hz, and errors will occur with the dwell test.

Setting up a Dwell: Under the “COMMAND” column click the word “Full Sweep” and it should open a drop down menu; select “DWELL out of the choices. Under the “DURATION TYPE” column click the word “CYCLES” and select “TIME” instead. Set your time and frequency. See Figure 4-15.

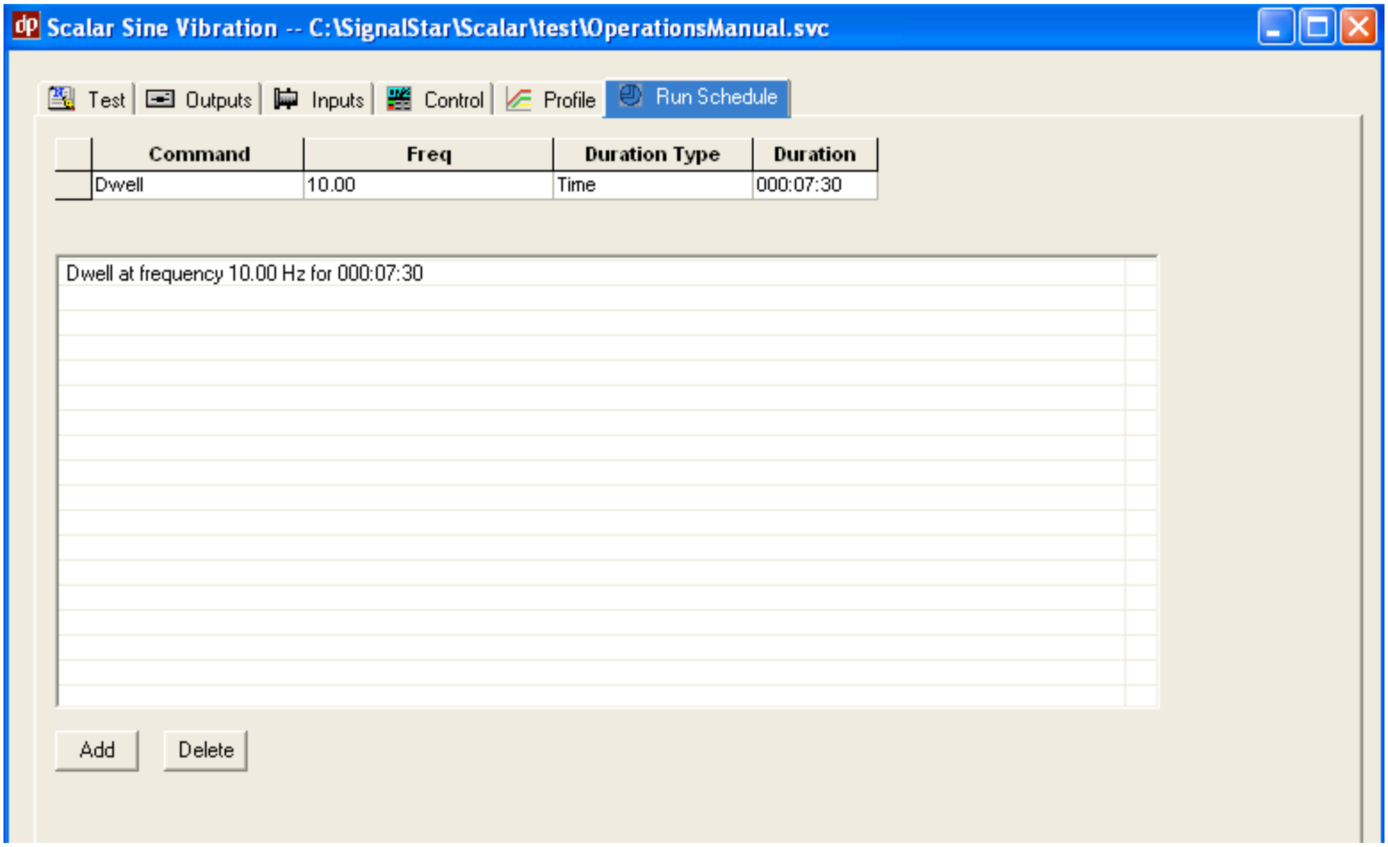


Figure 4-15: Screenshot to change the Run Schedule to a Dwell

Setting up a Sweep: Under the “COMMAND” column select “SWEEP”; set the start and stop frequency (they must be within range of what is set in the “CONTROL” and “PROFILE” tab). “DURATION TYPE” should be set to “TIME”. Look back into the “CONTROL” tab and look at the time duration for a full test; set the time duration in the run schedule to be about 20 seconds longer and 10-20 Hz shorter so there is time to stop the test. Make sure to set “SAVE INTERVAL” to “EVERY 1 SWEEP”. See Figure 4-16.

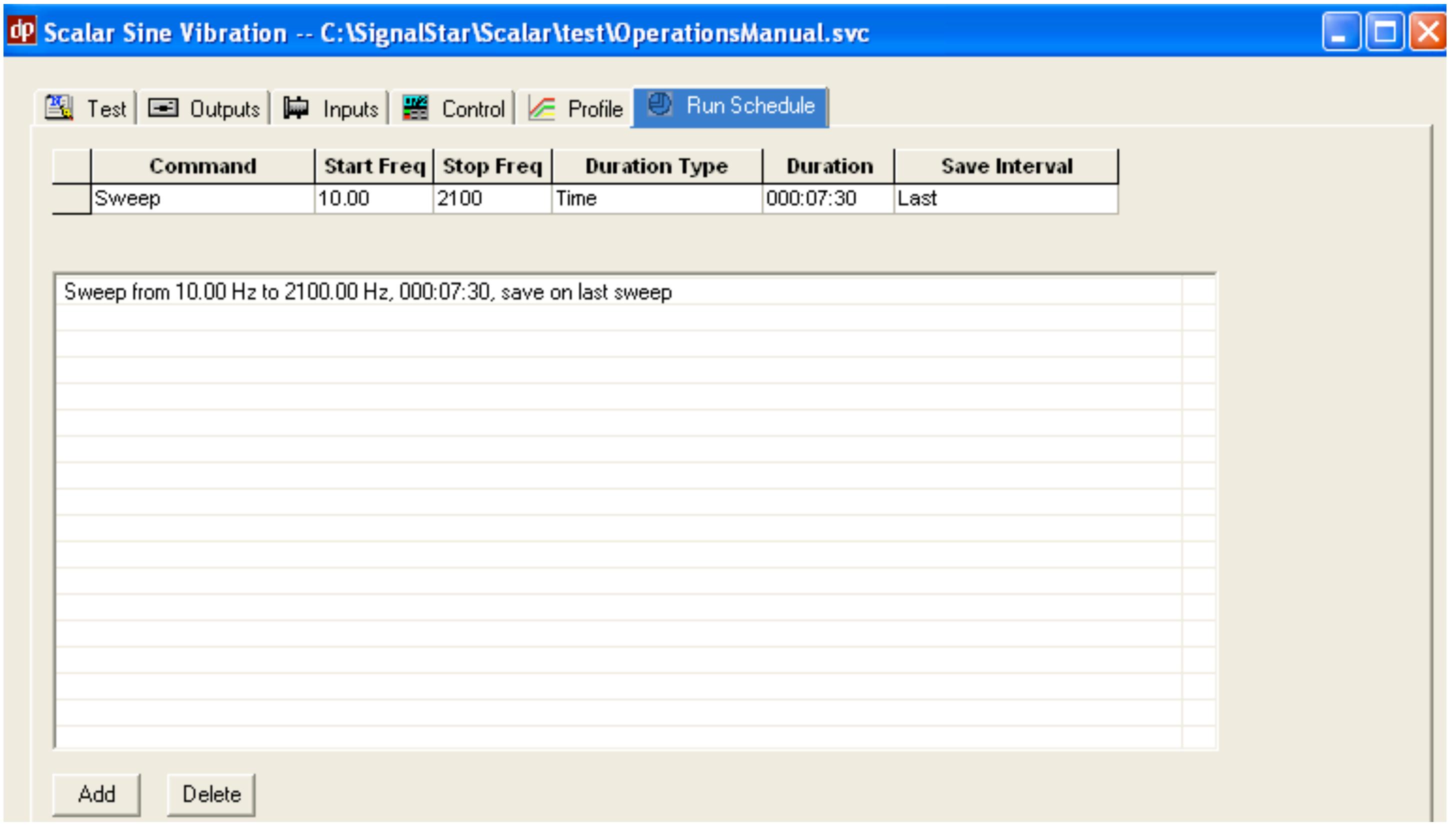


Figure 4-16: Screenshot to change the Run Schedule to a Sweep

15) Click "APPLY" then "OK" once all the tabs have been setup.

16) Click "DISPLAY" at the top toolbar; select "NEW GRAPH". See Figure 4-17.

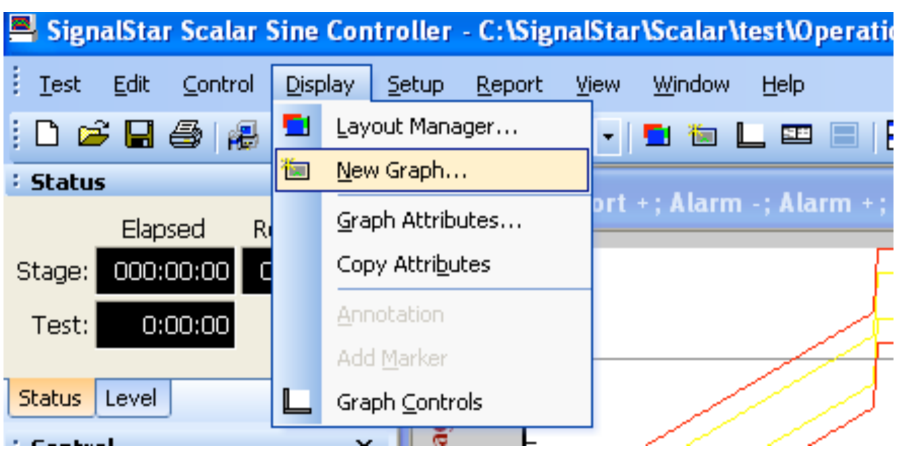


Figure 4-17: Screenshot of configuring a new graph

17) Under “SX-Spectrum” select S2 (this is the channel 2 for the sound pressure); click “OK” and this will bring up the graph. See Figure 4-18.

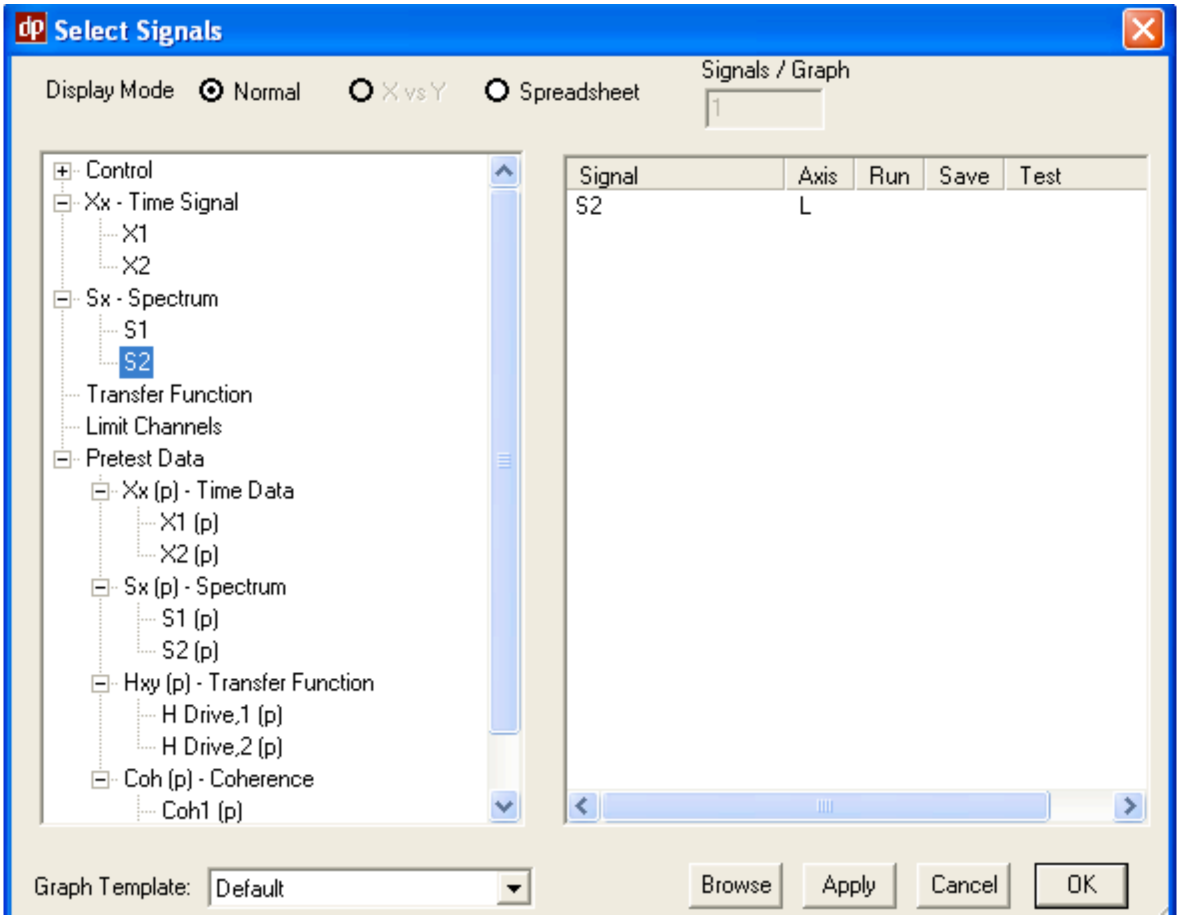


Figure 4-18: Screenshot to select preferred data

18) Click “DISPLAY” at the top toolbar again and then select “GRAPH CONTROLS”. Make sure both buttons are on “LIN” and not “LOG” for the X and Y axes.

Running and Saving a Test:

1) Make sure the sound pressure level meter is turned on.

2) Click the "INIT: button in the Signal Star Scalar program (it is dark green). See Figure 4-18.

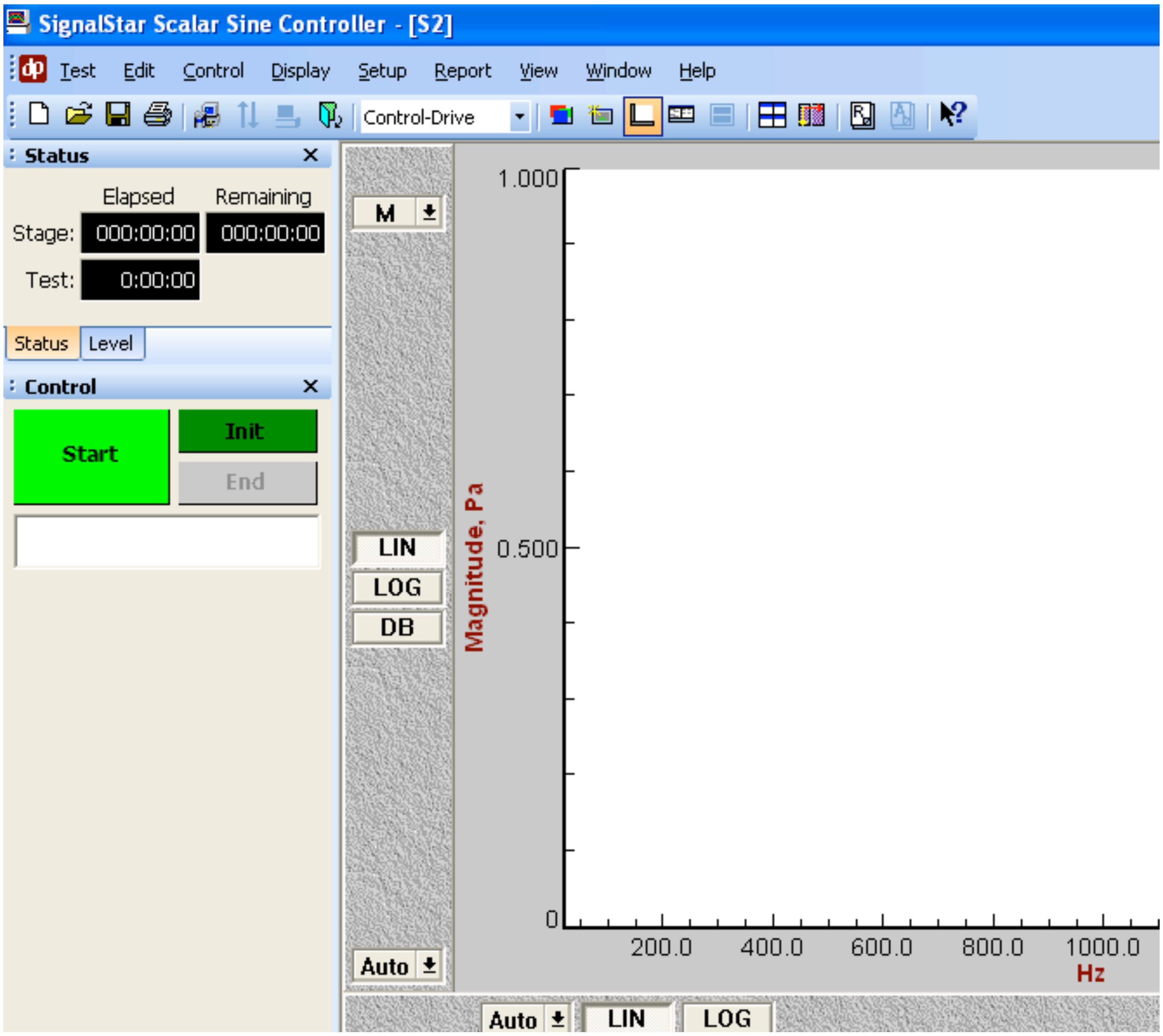


Figure 4-18: Screenshot of main testing screen

3) Click "YES" for overwriting last run.

4) A message, see Figure 4-19, will pop up alerting the operator to push the "STOP" button (the red button plugged into T2 on the Abacus); press it.

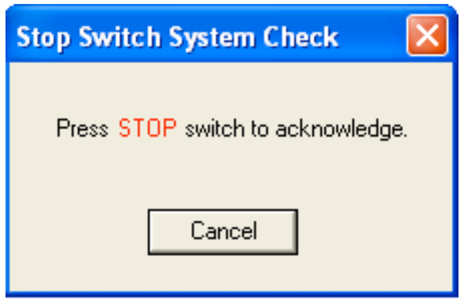


Figure 4-19: Pop up message to press “STOP” button

5) Click “START” after the "Ready to start" message appears in the control prompt; it is located under the big green “START” button. See Figure 4-20.

Figure 4-20: Screenshot indicating the “START” button and control prompt message

6) After the Pre-Test runs, click "Start Test" in the “Pretest Report” window when it appears. See Figure 4-21.

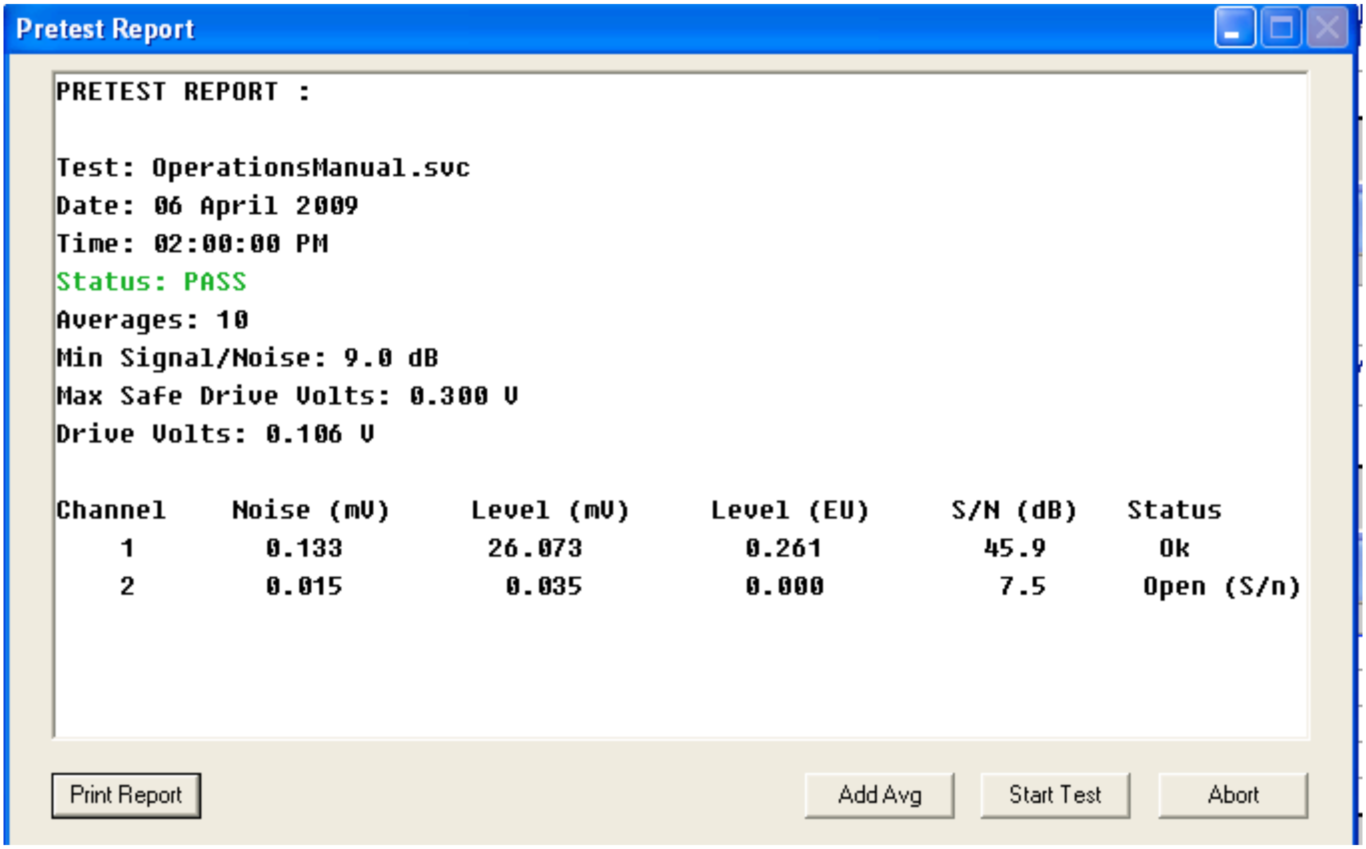


Figure 4-21: Screenshot of a “Pretest Report”

7) The test will run, and make sure to hit “STOP” after it reaches the desired max frequency. If not, the test may not save the data correctly and error will occur.

8) Right click the graph and scroll down to “GRAPH” and select “EXPORT”. This will save a raw file of all the data points. See Figure 4-22.

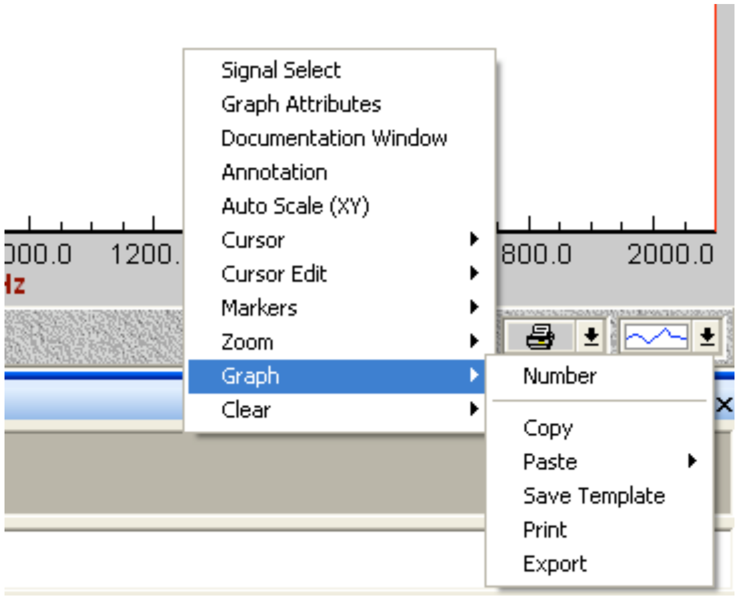


Figure 4-22: Screenshot of scroll down menu to graph

9) If a copy of the graph that appears in the screen is desired for reference, click the down arrow next to the printer symbol and select the two papers icon located at the bottom right of the graph. This will copy the image of the graph to the clipboard. For example, paste this in WordPad and save. See Figure 2-23.

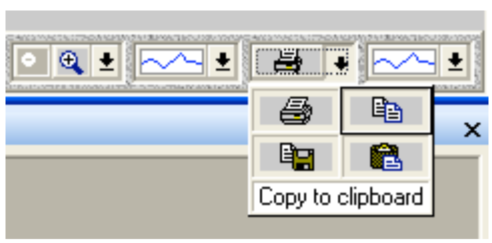


Figure 4-23: Screenshot of icons to copy graphs

Shutting Down:

1) Click "END" in the control prompt and save the test; select "TEST" from the top toolbar and go to "EXIT".
2) Hold the "STOP" button on the amplifier for about 5 seconds.
3) Turn the "GAIN" knob full counter clockwise.
4) Switch the "INTERNAL/EXTERNAL" switch over to "INTERNAL".

5) Turn the key to the “OFF” position.
6) Shut down the Abacus system by going to “START” on the desktop and selecting “TURN OFF COMPUTER”.
7) Select “Turn OFF”. The computer will shut down like normal.
8) When the monitor goes black, flip the “I/O” switch in the back to the “O” position.
9) Turn off the monitor using the power button on the front.
10) Unplug the three-prong power cable from the wall that is connected to the amplifier for safety.

4.2 dSpace, Matlab, and the PiezoMechanik Amplifier

4.2.1 Hardware Setup

Amplifier (PiezoMehcanik)

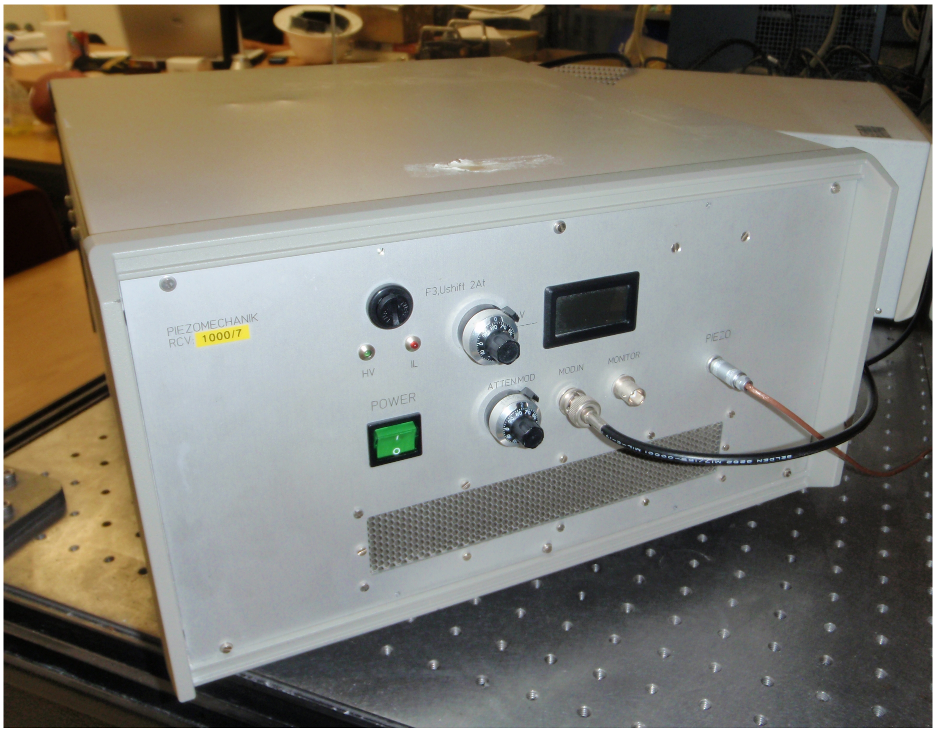


Figure 4-24: PiezoMechanick Power Amplifier

1) Unscrew the fuse, labeled "F3" on amplifier, and check to see if it is blown. See Figure 4-25.
2) To connect voltage input signal into amplifier, use a BNC cable from the source and connect the other end to the "MOD IN" input channel. See Figure 4-25.
3) To connect piezo materials to amplifier, plug the associated Lemo connector from the piezo actuator to the port "PIEZO". See Figure 4-25.
4) To turn power amplifier on, flip the green "POWER" switch to the "I" position. See Figure 4-25.
5) To adjust the voltage bias of the system, adjust the "Ushift 2At" knob. See Figure 4-25.

6) Check the voltage output by viewing the LED display screen located above the two BNC ports. See Figure 4-25.

Figure 4-25: Close up view of control of the PiezoMechanik

7) To turn power amplifier off, flip the green "POWER" switch to the off position.

Data Acquisition (dSpace)

1) Connect the dSpace unit to the associated computer by using the dSpace PCI card and connecting cables.
2) Make sure either the yellow fiber optic cable or the Ethernet like cable is used to connect the dSpace and computer system.
3) Connect external devices such as capacitor probes and LVDTs using BNC cables to the data acquisition port board.
4) To turn dSpace on or off, flip the green power switch to the on or off position.

4.2.2 Software Setup

Matlab and Simulink (Control Code Source)

1) Open Matlab 6.5.1 by double clicking associated icon.

2) After Matlab loads, check the display in the "Command Window" and make sure the dSpace configuration is "okay" and that the "RTI" and Simulink does not list any errors. See Figure 4-26.

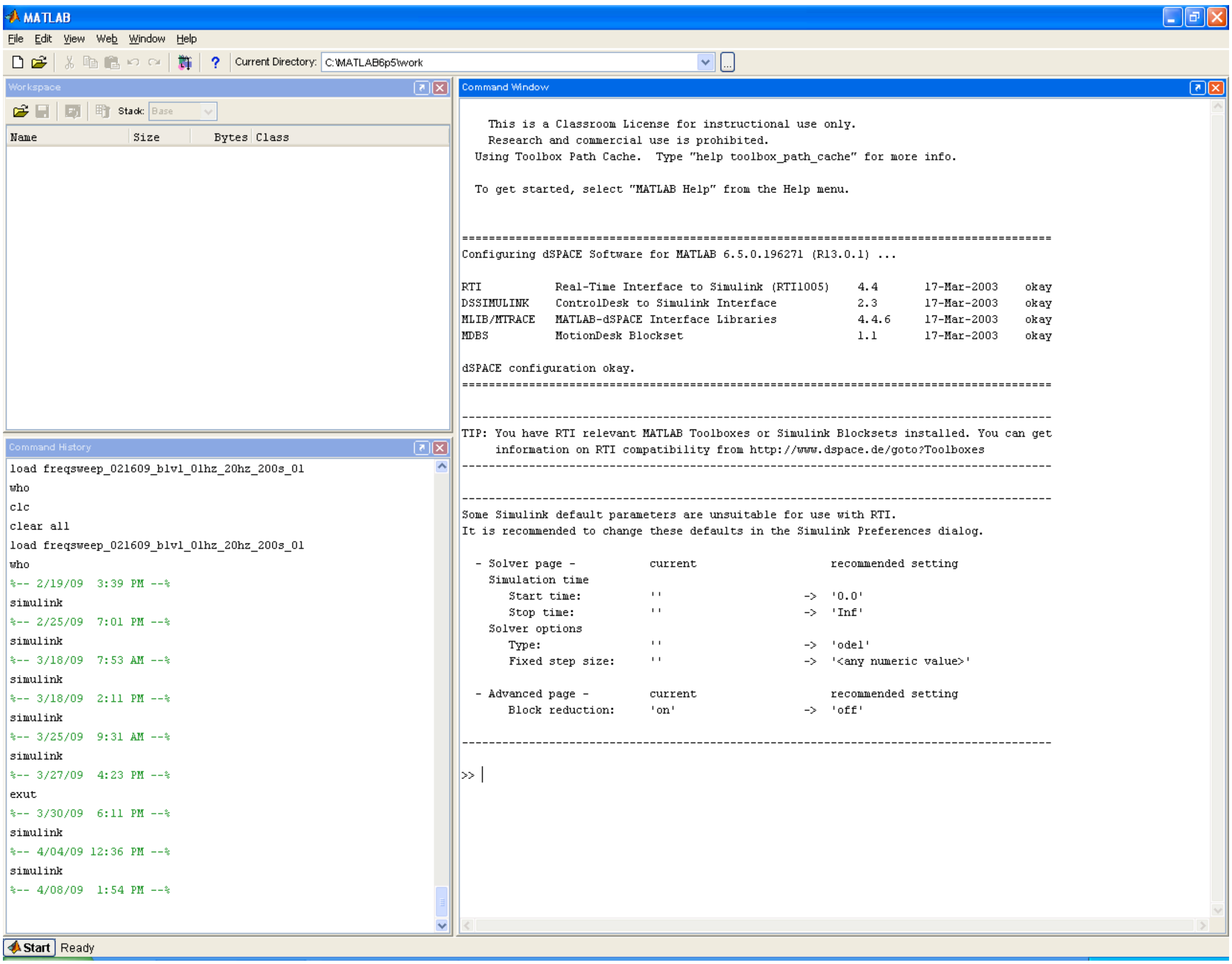


Figure 4-26: Screenshot of Matlab display window at startup

3) Make sure the current directory is set to the correct folder containing the Simulink files; this is where data will be saved from dSpace. See Figure 4-27.

4) To change the directory, press the icon that has three dots located next to the "Current Directory:" scroll down menu and select correct folder. See Figure 4-27.

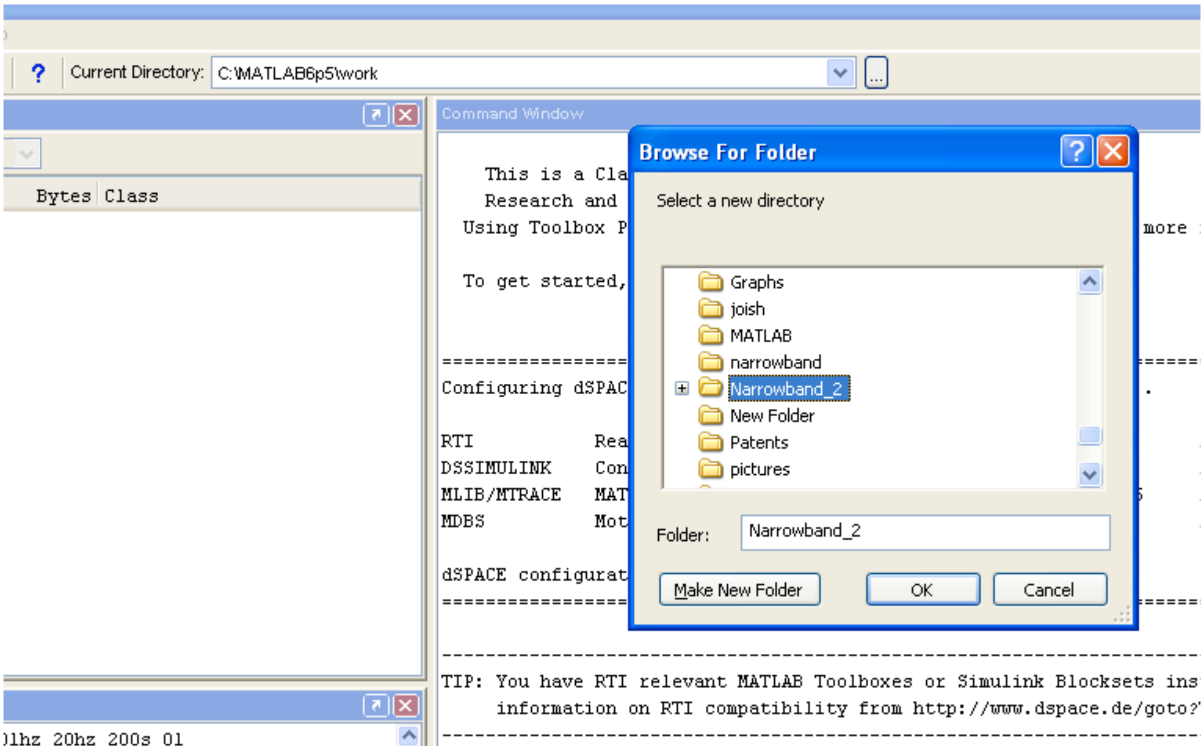


Figure 4-27: Screenshot of the "Current Directory" menu

5) Open the Simulink file containing the control code necessary for testing by using the "Open File" tab in the "File" menu.

6) The Simulink file should contain the associated dSpace blocks to have correct instrumentation linkage for data analysis; use the Simulink toolbar by typing "Simulink" into the Matlab "Command Window" to add dSpace blocks and the like.

7) Turn dSpace on before the Simulink file is run by flipping the green on/off switch on the dSpace unit.

8) Run the Simulink file by pressing the icon looks like a rectangle that has three arrows pointing down on it. See Figure 4-28 and Figure 4-29.

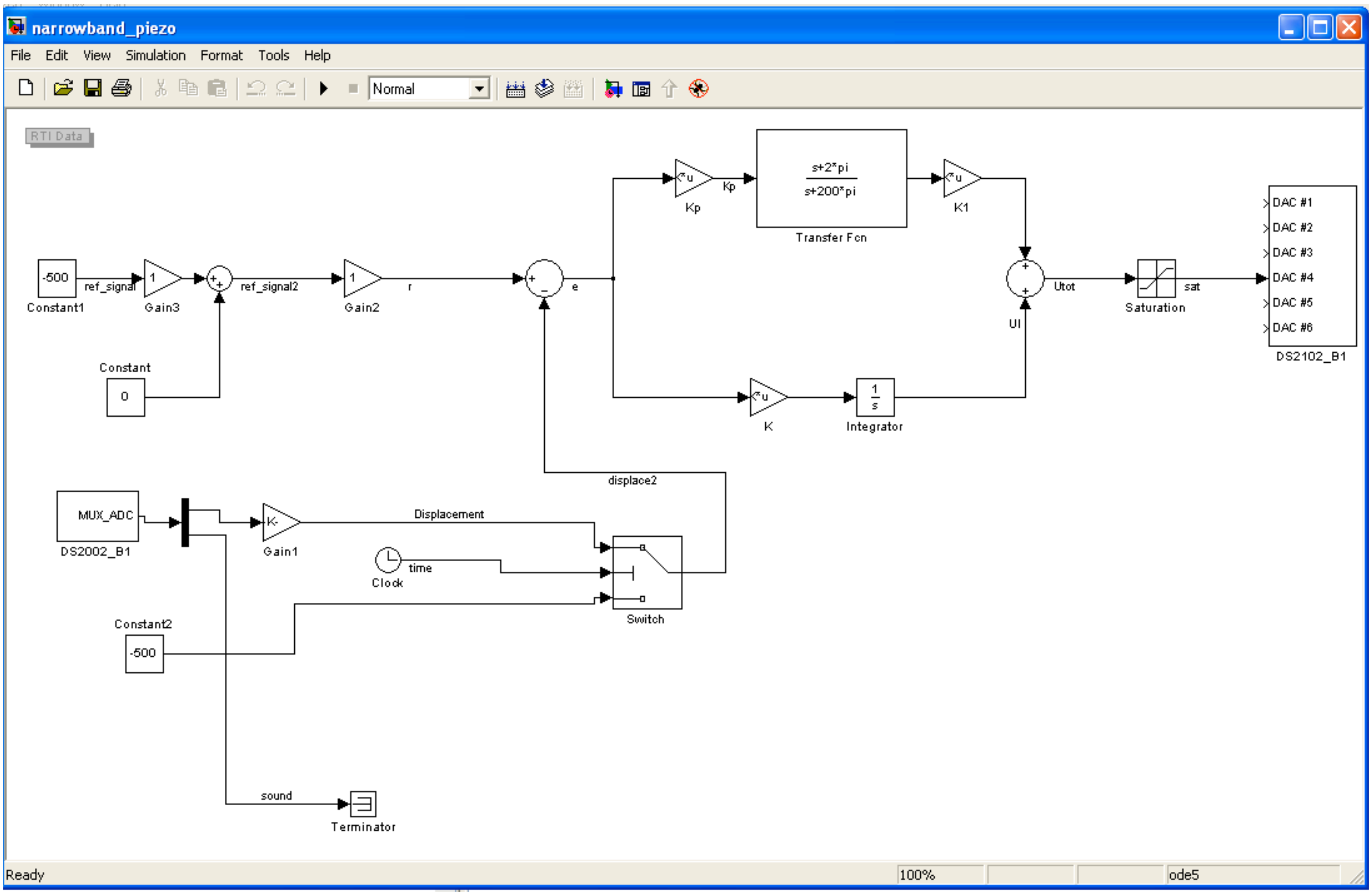


Figure 4-28: Screenshot of a Simulink diagram

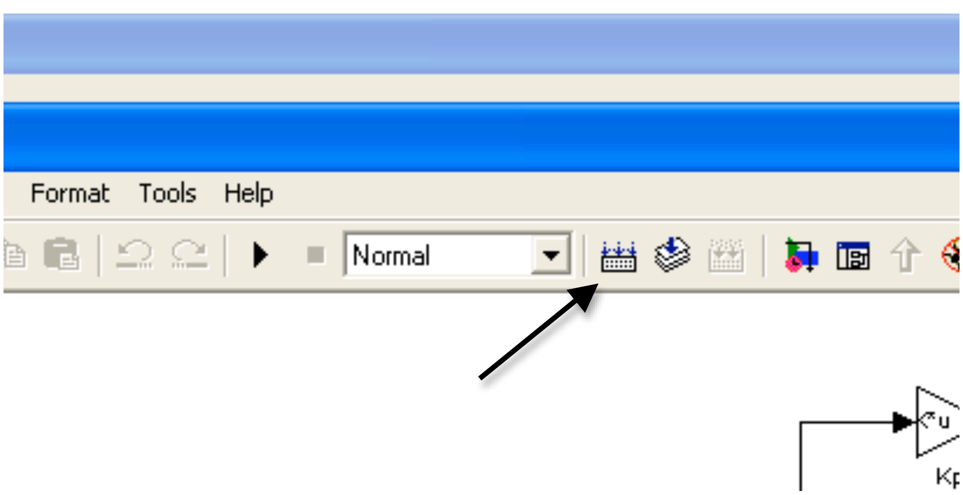


Figure 4-29: Close up screenshot of the run icon

9) Messages should appear in the Matlab “Command Window” as the Simulink runs and compiles; check for error messages and once the file is loaded, testing can commence.

dSpace Control Desk (Data acquisition runtime software)

Matlab/Simulink run independently from dSpace Control Desk. Unless data needs to be collected or view in real-time, Control Desk does not need to be used.

1) Open dSpace Control Desk by double clicking the associated icon.
2) Check that there are no errors and that the RTI has loaded by viewing the commands listed in the “Log Viewer”. See Figure 4-30.
3) Load an experiment by going to the “File” menu and selecting “Open Experiment.”
4) Select the correct experiment that is associated with the Simulink file loaded; the dSpace Control Desk file is dependent on its corresponding Simulink file. See Figure 4-30.

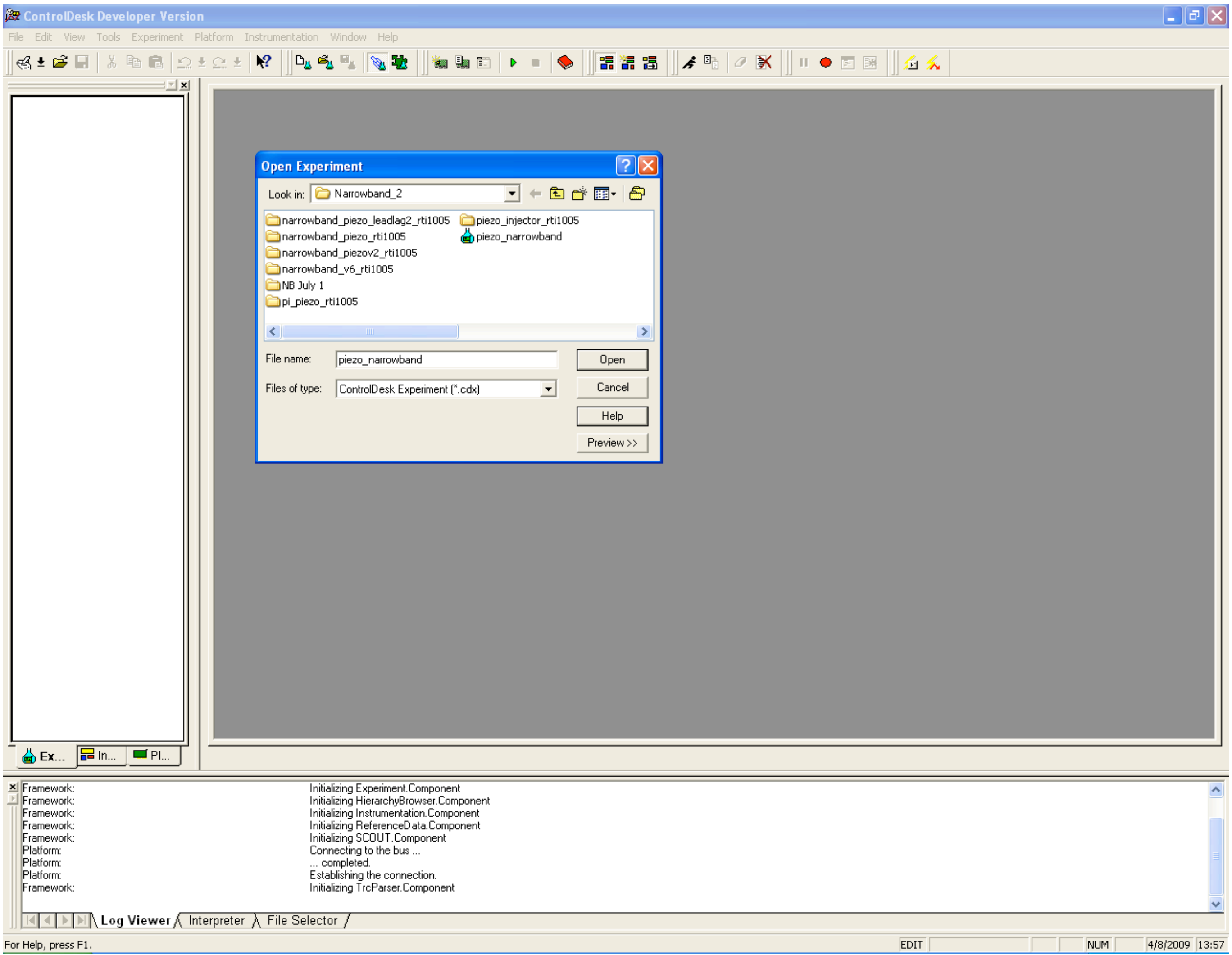


Figure 4-30: Screenshot of the Control Desk window and "Open Experiment" window

5) Once the file has loaded, make any desired changes to the graphs and run by pressing F5. Depending on what types of graphs and data displays are used, one should see some activity in the graph windows. See Figure 4-31.

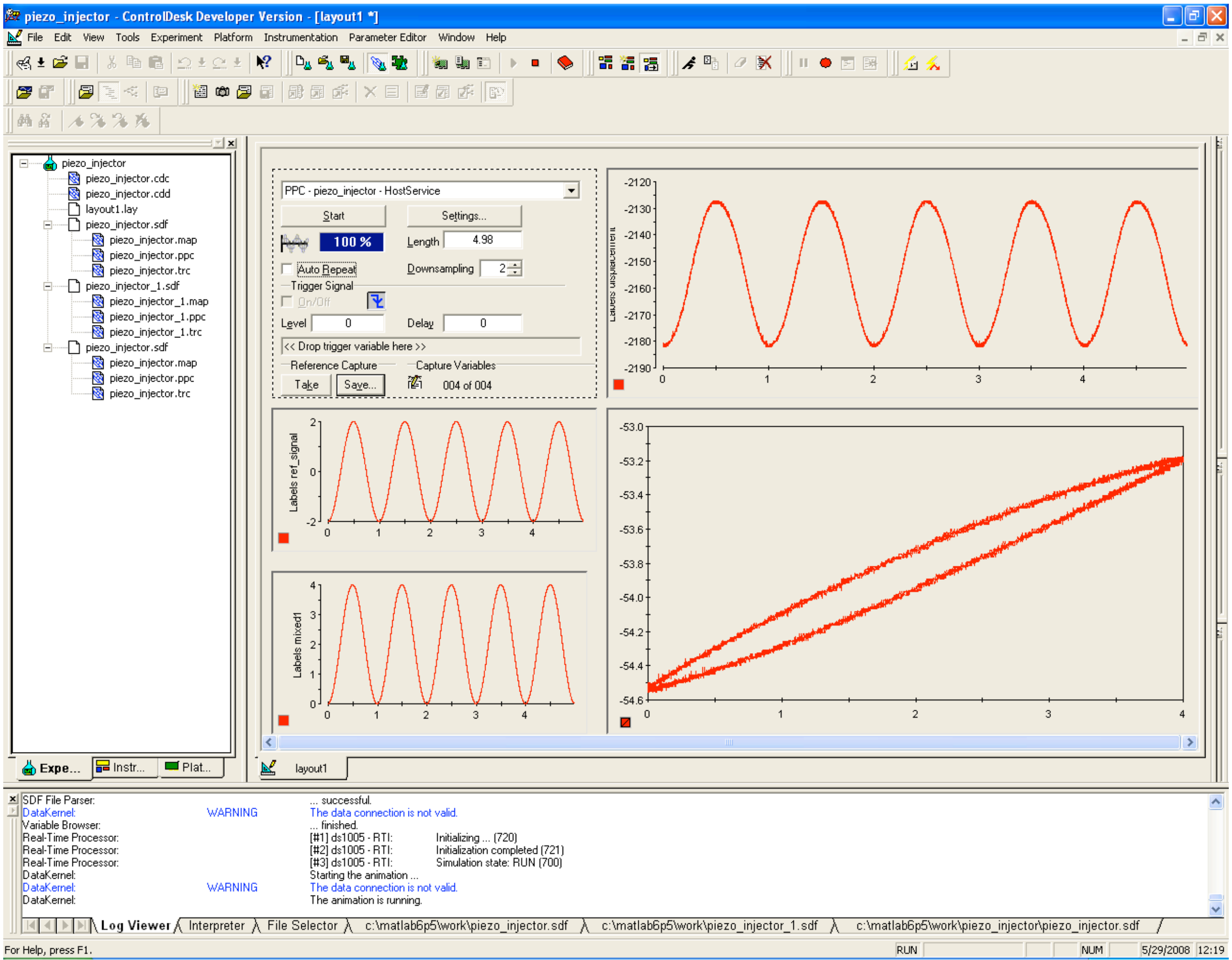


Figure 4-31: Screenshot of graph activity

6) Make sure that the correct Simulink file name appears in the drop down menu located above the "Start" button. See Figure 4-32.

7) To start and stop the simulation from running, click the "Start" button. See Figure 4-32.

8) To change the length of time for each portion of testing and data collection, change the value in the area next to "Length". See Figure 4-32.

9) To collect data, make sure the desired "Capture Variables" have been loaded and click the save button. To add a "Capture Variable," the data recorded during the test, drag the desired variable from menu under the "File Selector" tab at the bottom of the screen to the small icon underneath the "Capture Variables" area. See Figure 4-32.

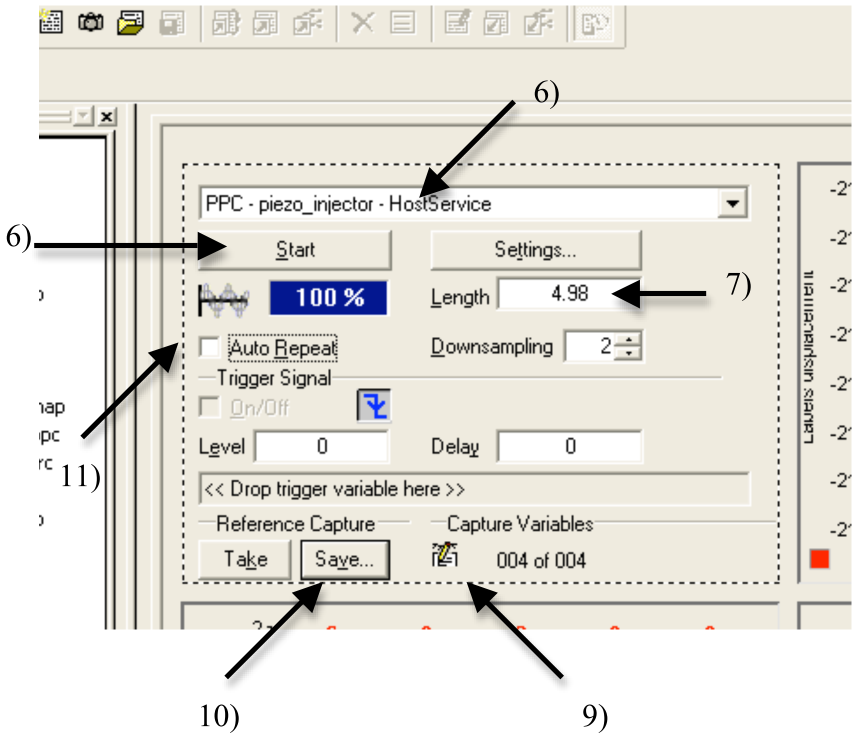


Figure 4-32: Screenshot for steps 6) – 11)

10) To save data, press the "Save" button and then a generic "Save as" window will appear. See Figure 4-32.

11) Use the "Auto Repeat" option to select or unselect the data repeating over the span of time chosen in "Length". See Figure 4-32.

12) If the simulation runtime ends and another test run is desired, re-load the Simulink file and then repeat step 5).

13) Once testing is completed, close the dSpace Control Desk window by selecting either the "X" at the top of the window or "Exit" from the drop down "File" menu.

5 Converting Raw Data

In order to record the sound power level emanating from the test bed during the tests a sound level meter, see Figure 4-2, was used as the recording device. The sound level meter used for testing displayed a digital reading in decibels (dB); however, the output signal to the data acquisition system was in volts. It became apparent upon examining the data that the meter had several 20dB ranges. This lead to the conclusion that each time the sound level meter switched ranges the voltage reading started back at its base reading (between 0.5V and 1V) as displayed in Figure 5-1. Make notice of the sharp drops; these are the transitions between ranges.

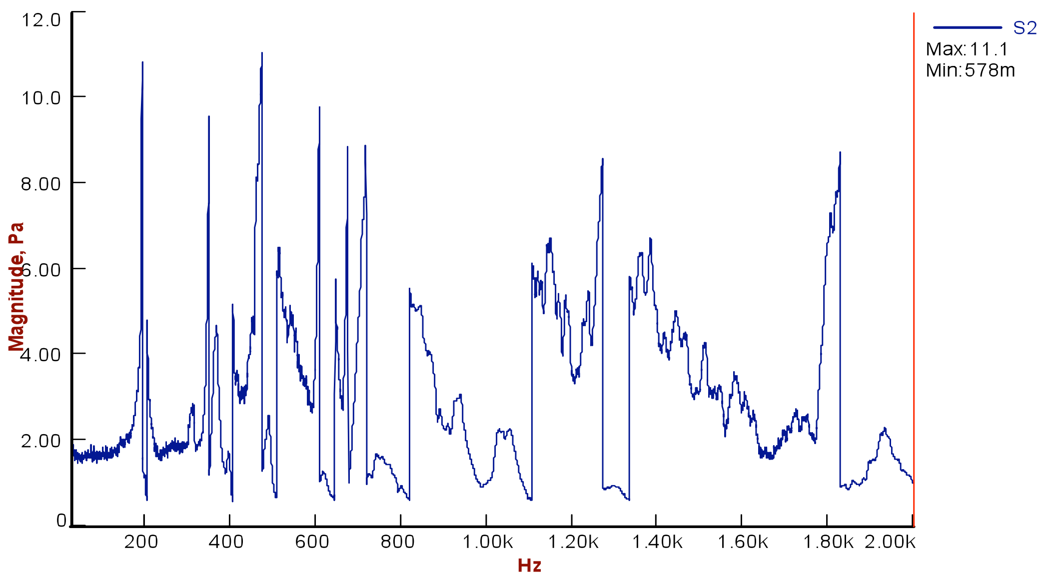


Figure 5-1: Raw data collected using sound level meter

The change in range is made evident by a very rapid change from a high voltage reading between 9V and 11V to the base reading. Using information from the sound level meter user manual, the company technical support team, and direct experimental comparison with other meters, a linear relationship [dB= (2.582)(voltage out)+37.16] was determined to convert from the voltage output to decibels. To compensate for the 20 dB range change, 20dB was added when the range shifted up and subtracted when the range shifted down. Figure 5-2 below shows the converted data from figure 5-1 above.

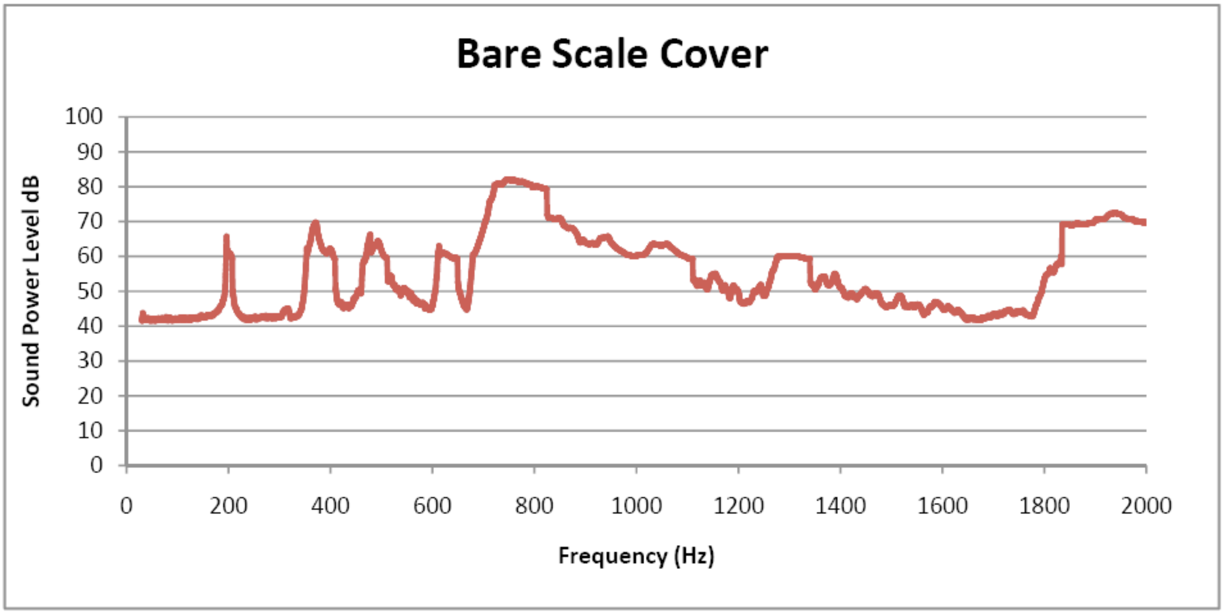
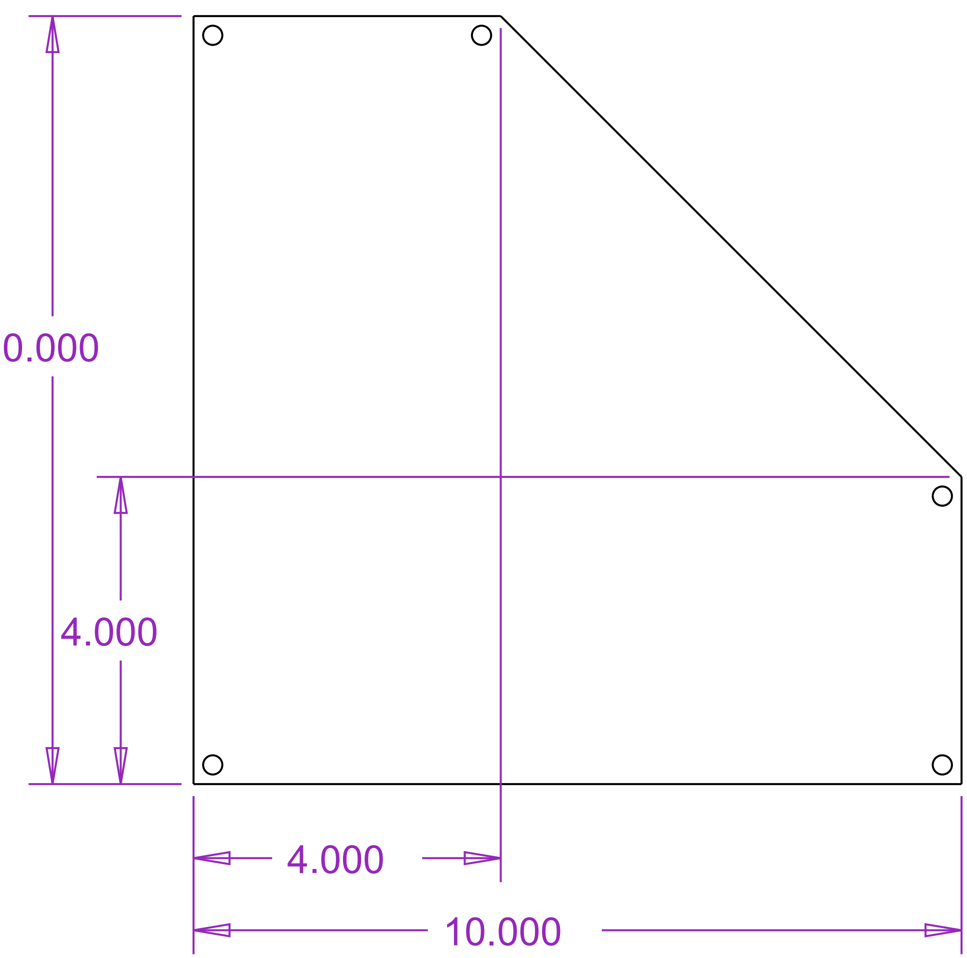


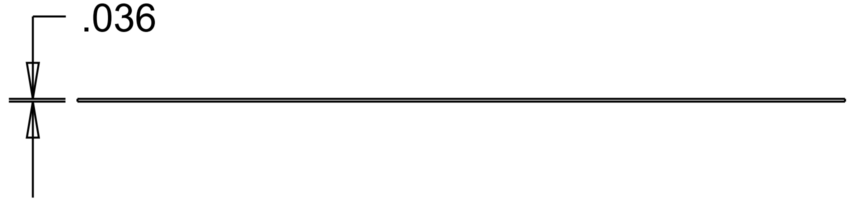
Figure 5-2: Analyzed data using method described

Appendix A1: Pro-E Drawings

The following drawings are included as a reference for hole location, sizing, and part reproduction.

SCALE	0.400
Tolerance	+/-0.005

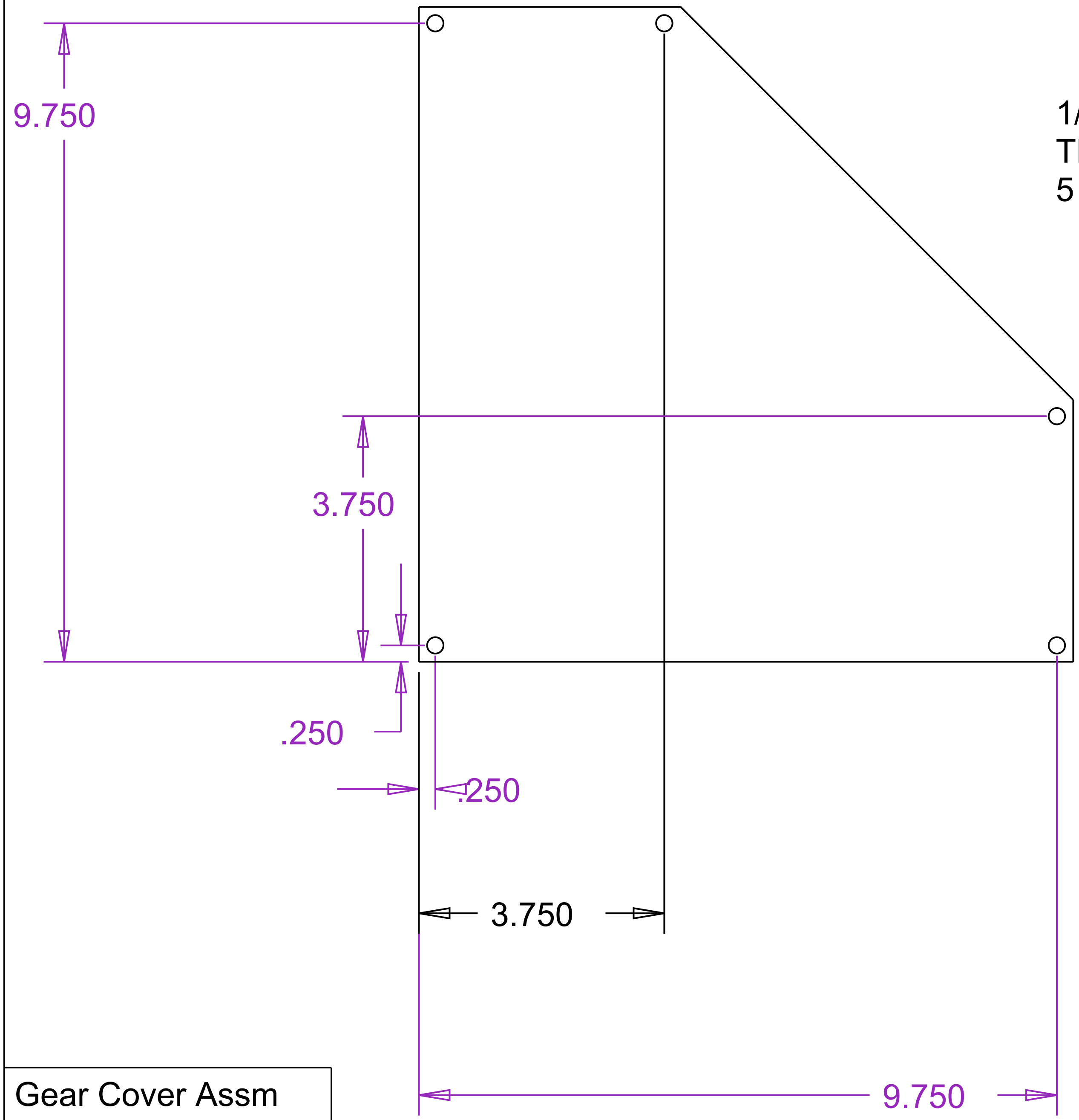




Gear Cover Assm	
Cummins Group 7	

	Barrier
SHEET #	001
LAST REVISION	04/07/09
REVISION #	001
DRAWING #	SD-P-001

SCALE 0.400
Tolerance +/-0.005

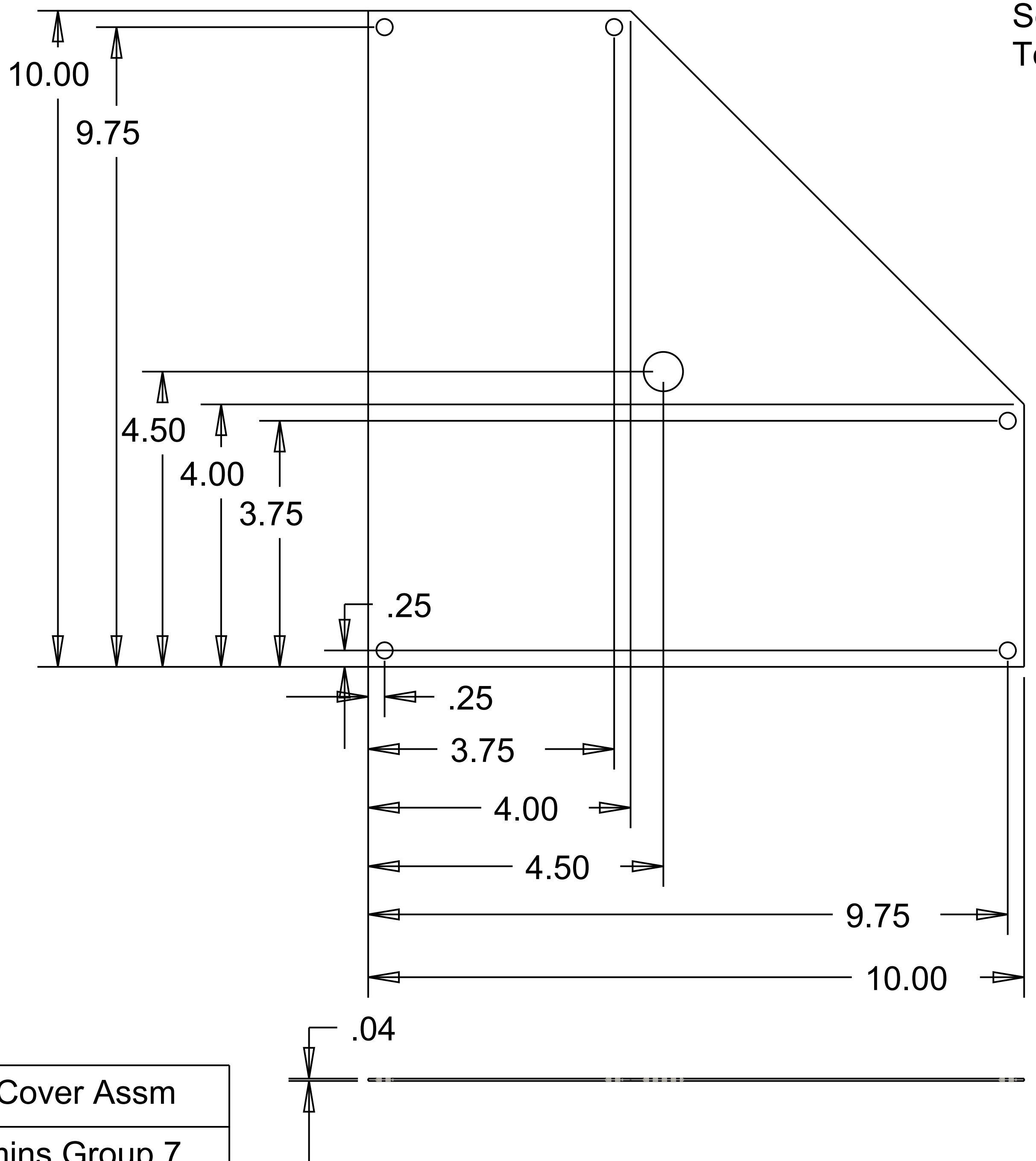


1/4 - 20 ↧
THRU ALL
5 PLACES

Gear Cover Assm	
Cummins Group 7	

	Barrier
SHEET #	002
LAST REVISION	04/07/09
REVISION #	001
DRAWING #	SD-P-001

Scale 0.400
Tolerance +/-0.005

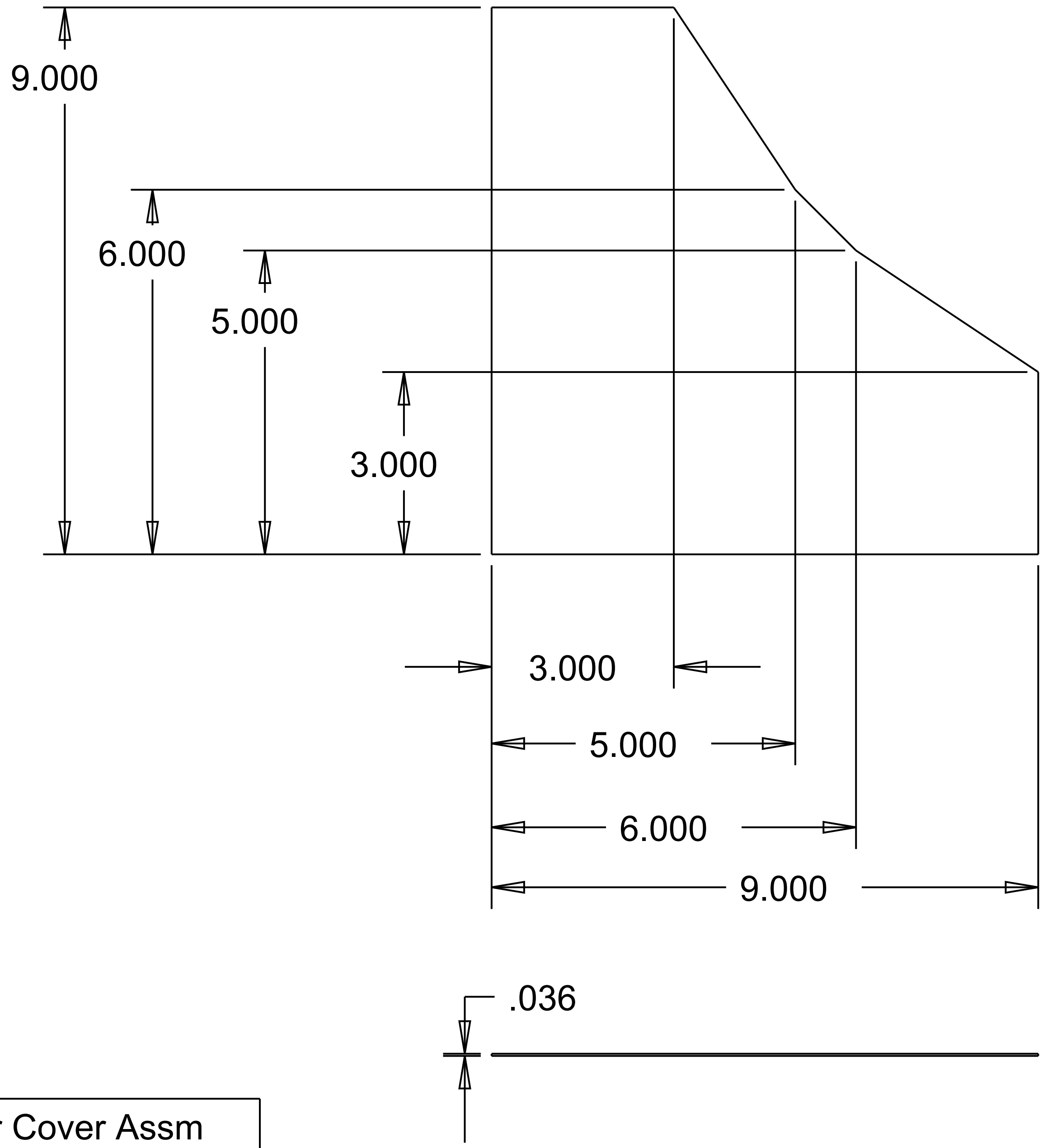


Sound Barrier Modified	
SHEET #	001
LAST REVISION	04/07/09
REVISION #	001
DRAWING #	SD-P-019

Gear Cover Assm

Cummins Group 7

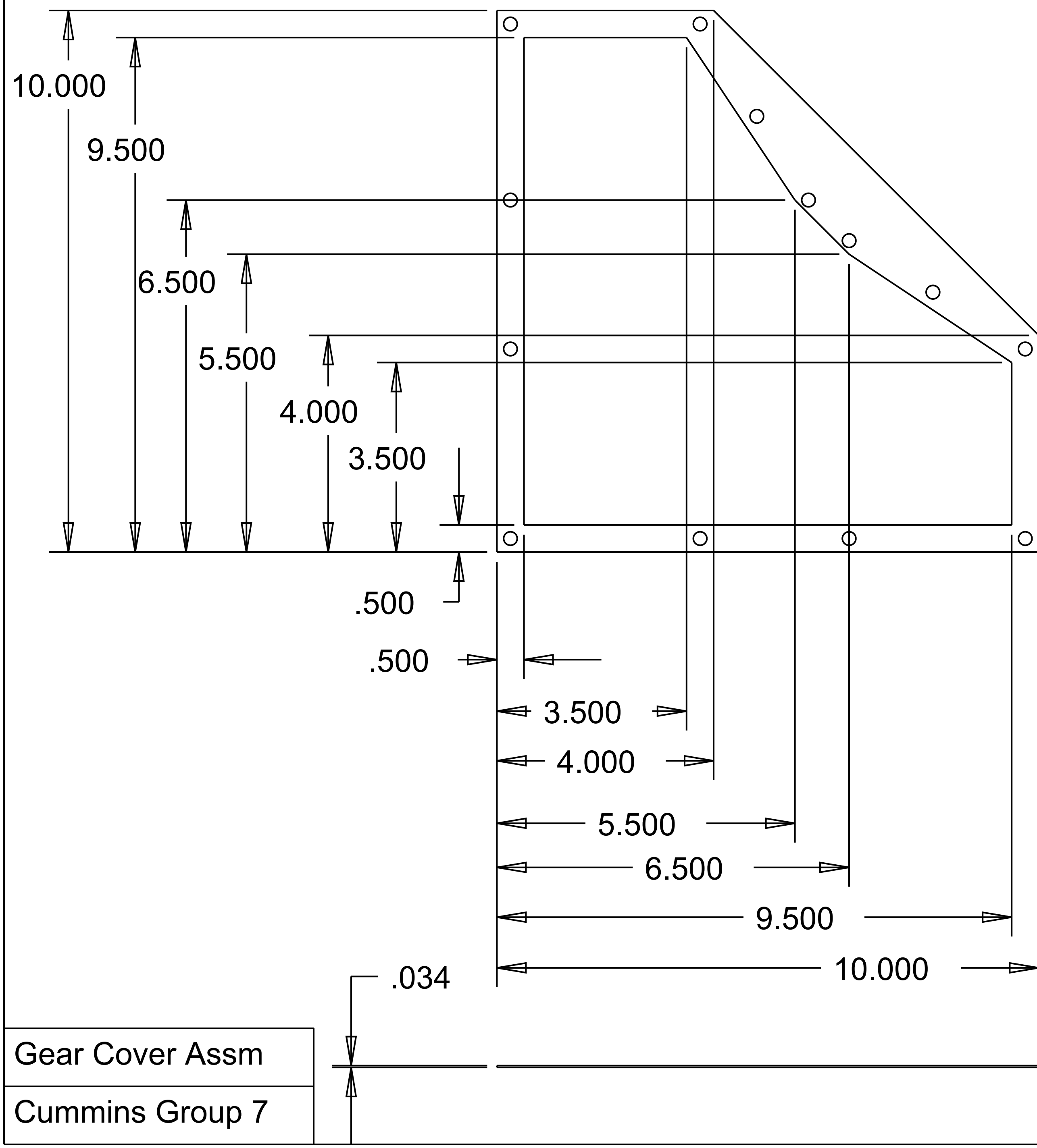
SCALE 0.350
Tolerance +/-0.005



Gear Cover Assm	
Cummins Group 7	

	Foam
SHEET #	001
LAST REVISION	11/21/08
REVISION #	001
DRAWING #	SD-P-002

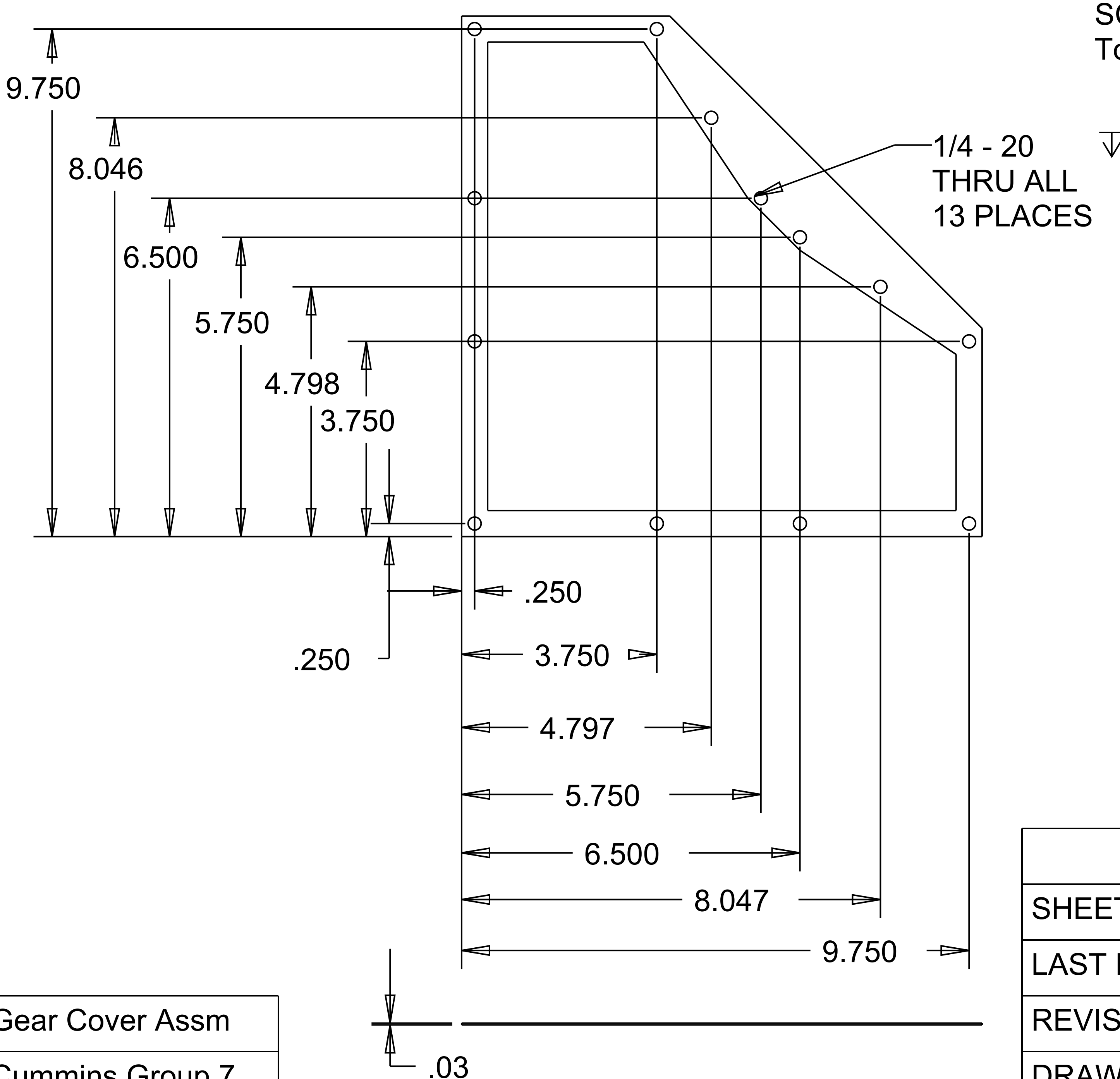
SCALE 0.350
Tolerance +/-0.005



Gear Cover Assm	
Cummins Group 7	

	Seal
SHEET #	001
LAST REVISION	11/21/08
REVISION #	001
DRAWING #	SD-P-005

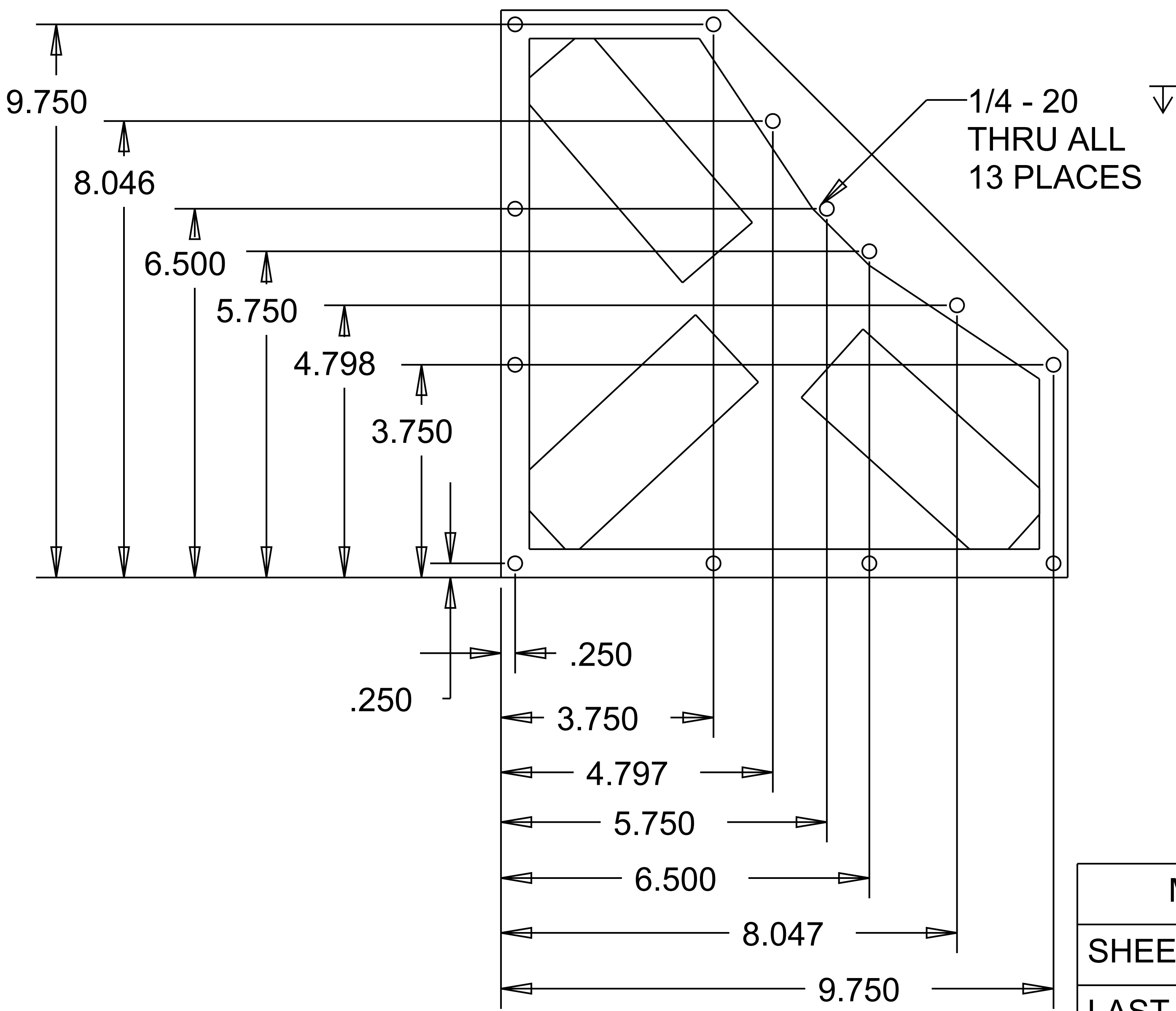
SCALE 0.350
Tolerance +/-0.005



	Seal
SHEET #	002
LAST REVISION	11/21/08
REVISION #	001
DRAWING #	SD-P-0015

Gear Cover Assm
Cummins Group 7

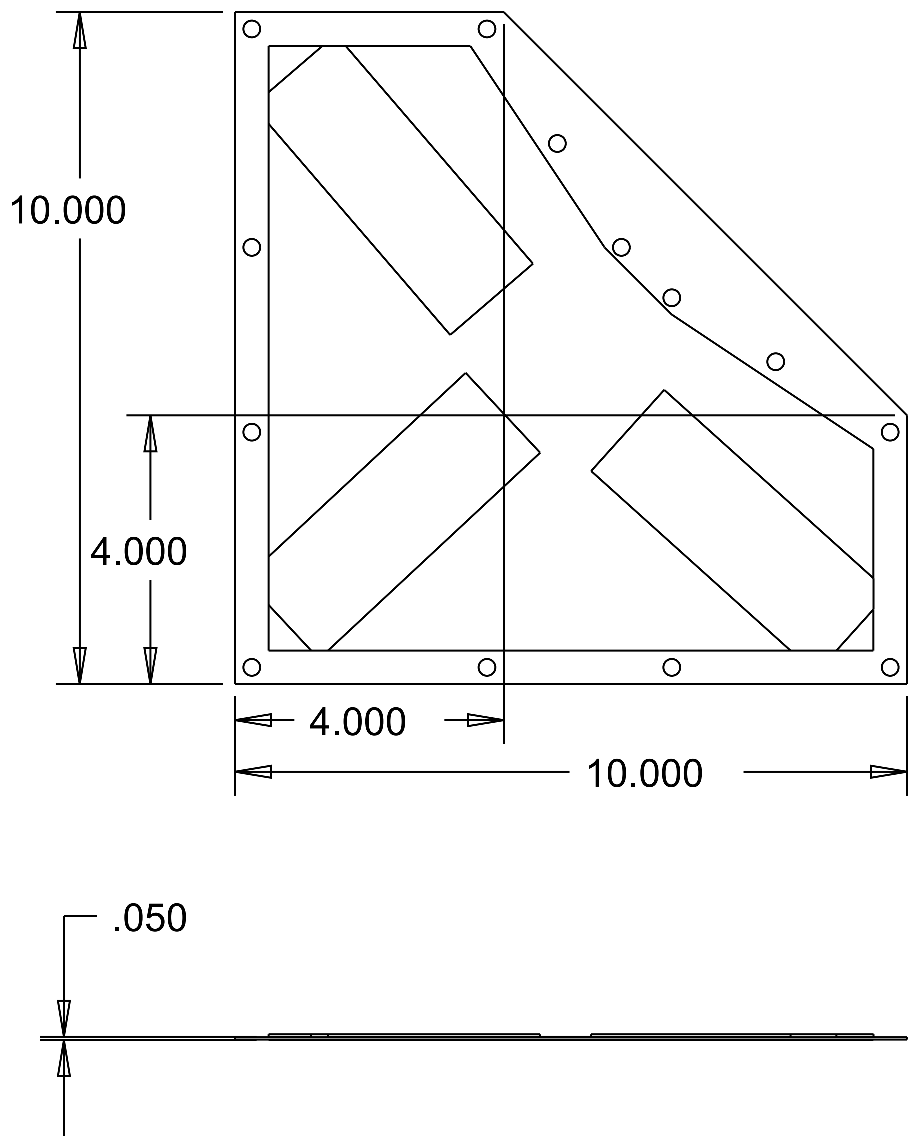
SCALE 0.350
Tolerance 0.005



Gear Cover Assm	
Cummins Group 7	

Model Cover with VB	
SHEET #	002
LAST REVISION	11/21/08
REVISION #	001
DRAWING #	SD-P-003

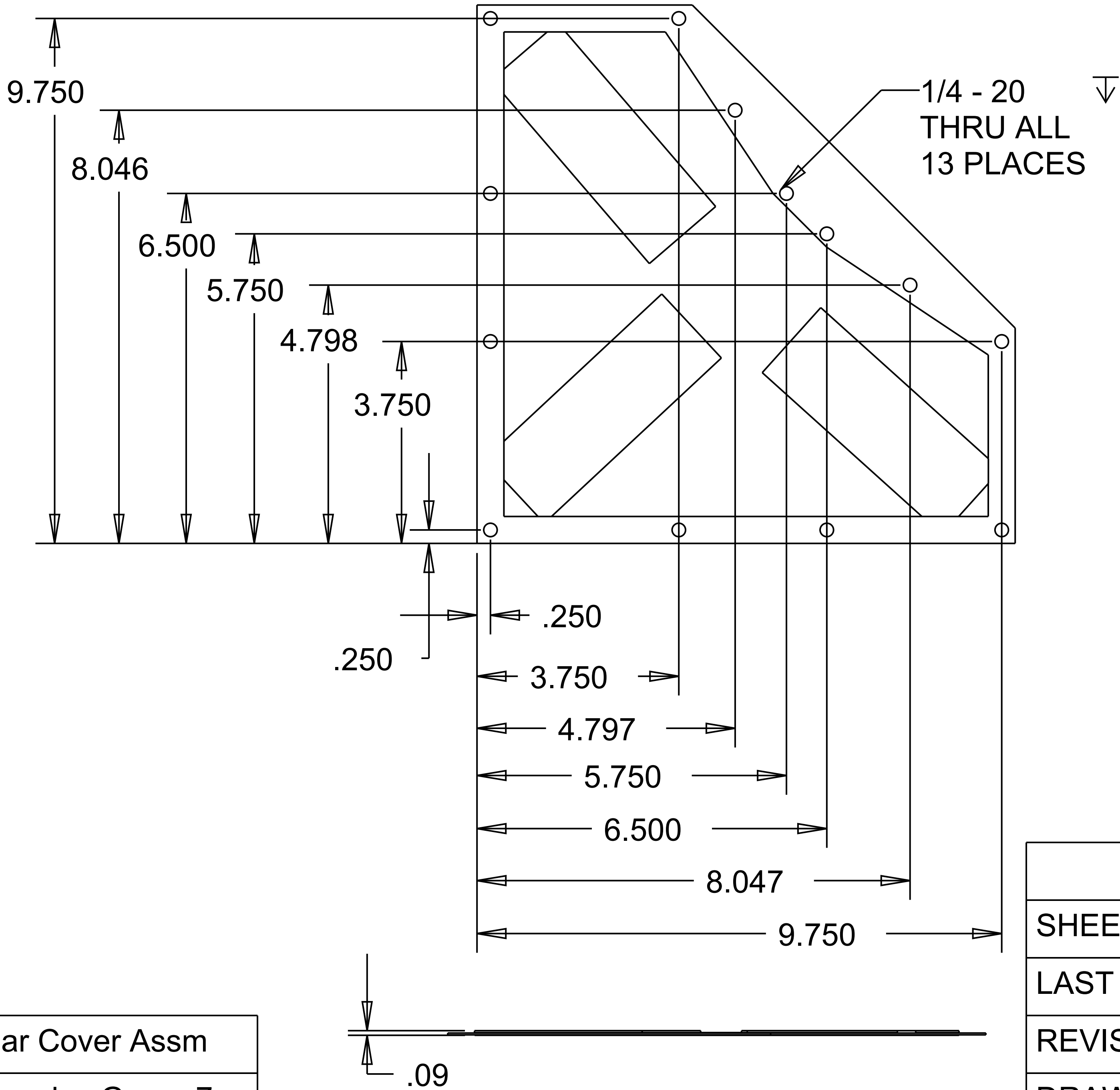
SCALE 0.350
Tolerance +/-0.005



Gear Cover Assm	
Cummins Group 7	

Model Cover	
SHEET #	001
LAST REVISION	04/07/09
REVISION #	002
DRAWING #	SD-P-003

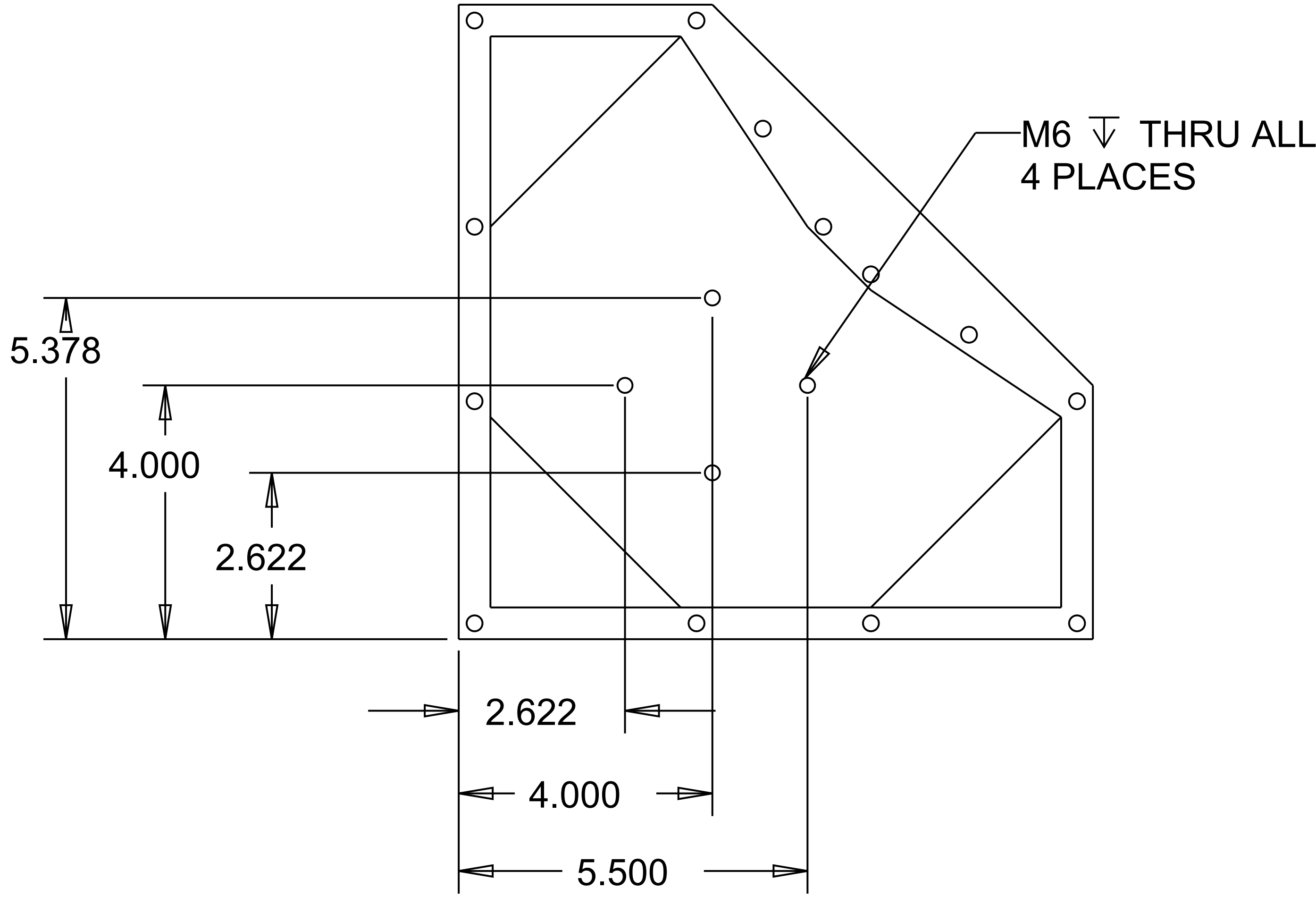
SCALE 0.350
Tolerance +/-0.005

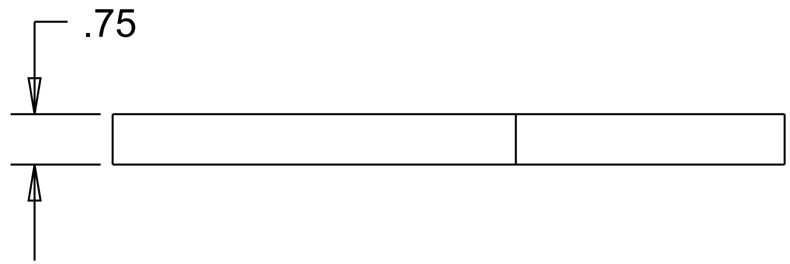


Gear Cover Assm	
Cummins Group 7	

Model Cover	
SHEET #	002
LAST REVISION	04/07/09
REVISION #	001
DRAWING #	SD-P-003

SCALE 0.350
Tolerance +/-0.005

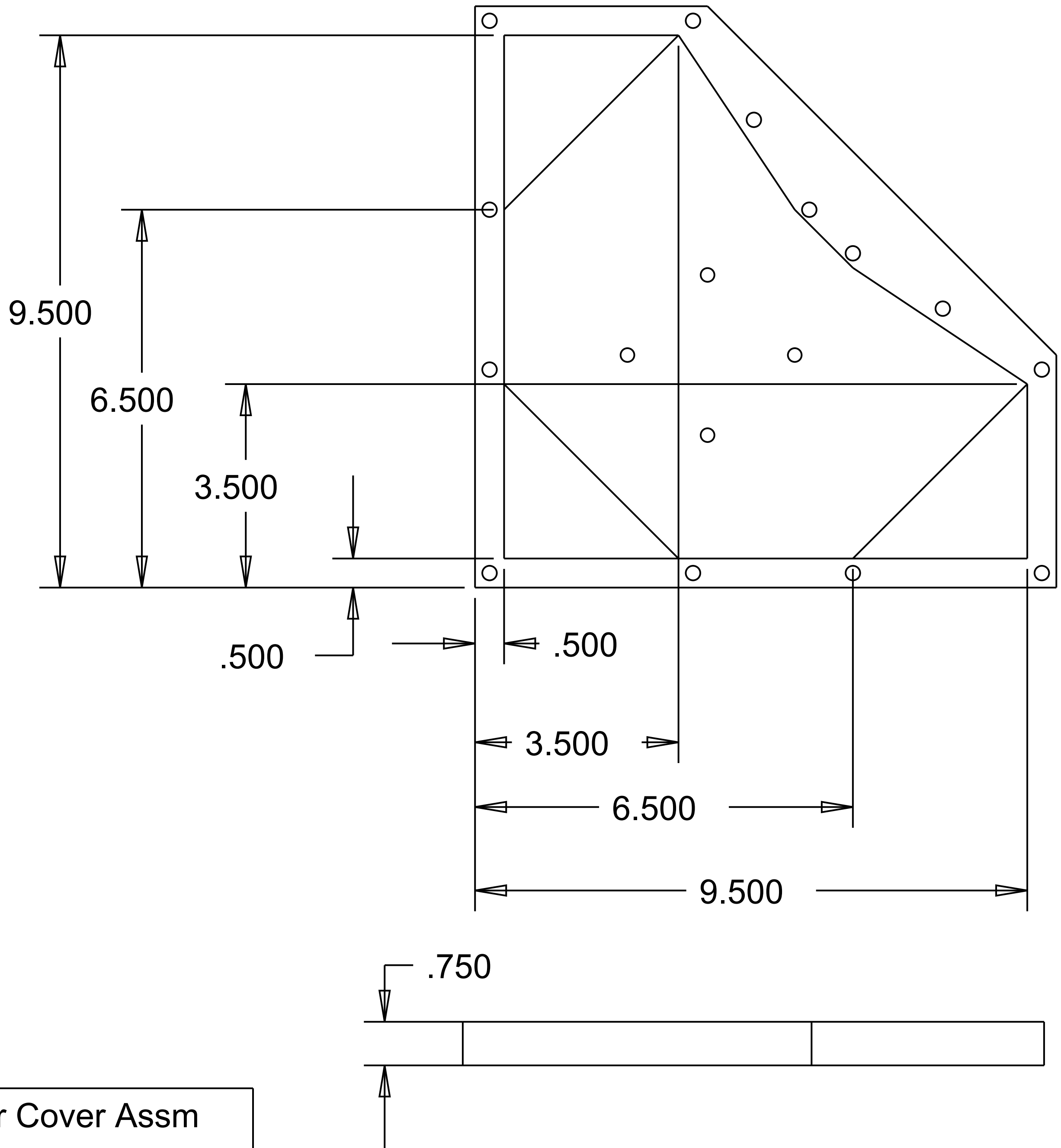




Gear Cover Assm	
Cummins Group 7	

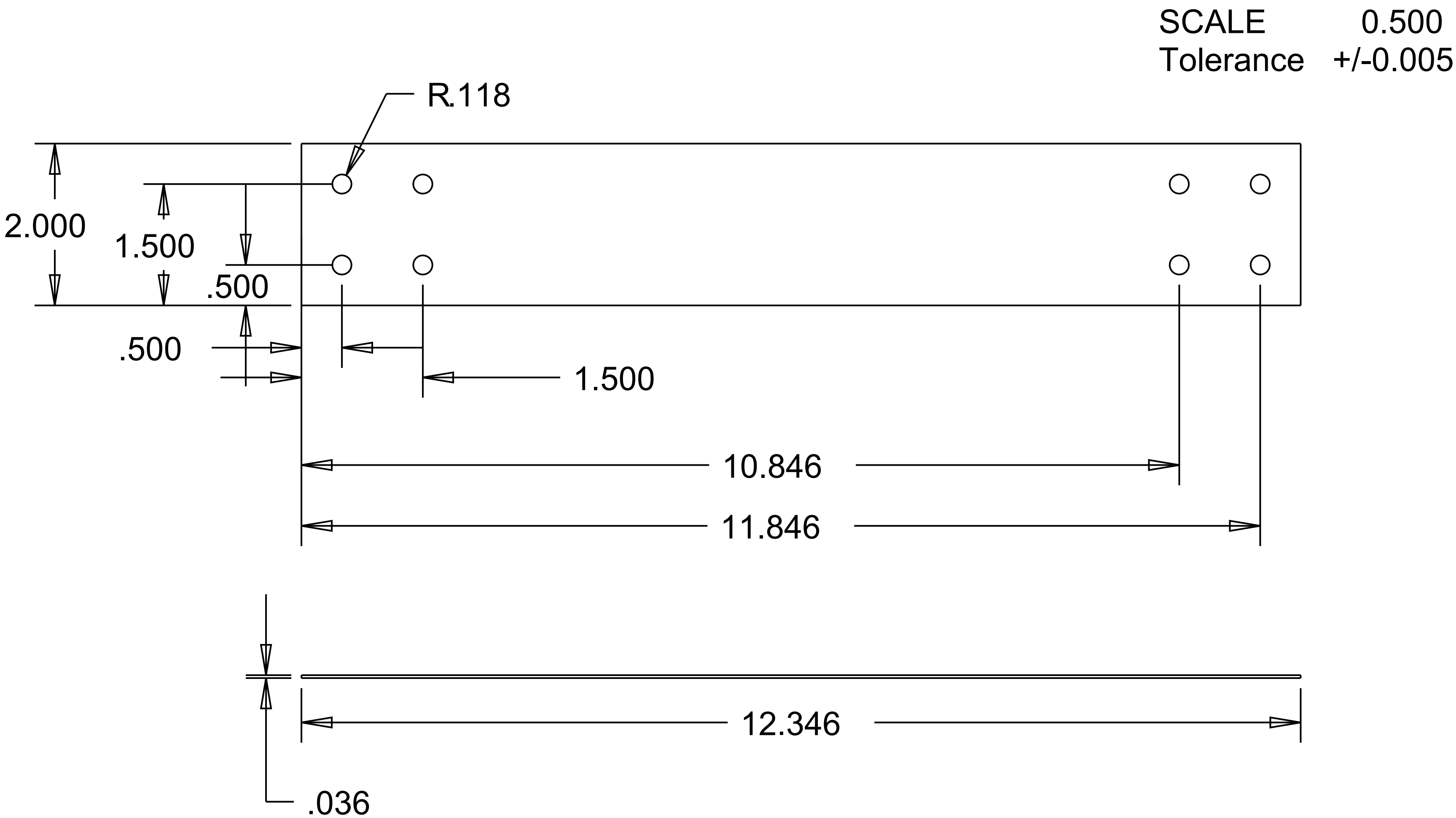
Model Housing	
SHEET #	003
LAST REVISION	04/07/09
REVISION #	001
DRAWING #	SD-P-004

SCALE 0.350
Tolerance +/-0.005



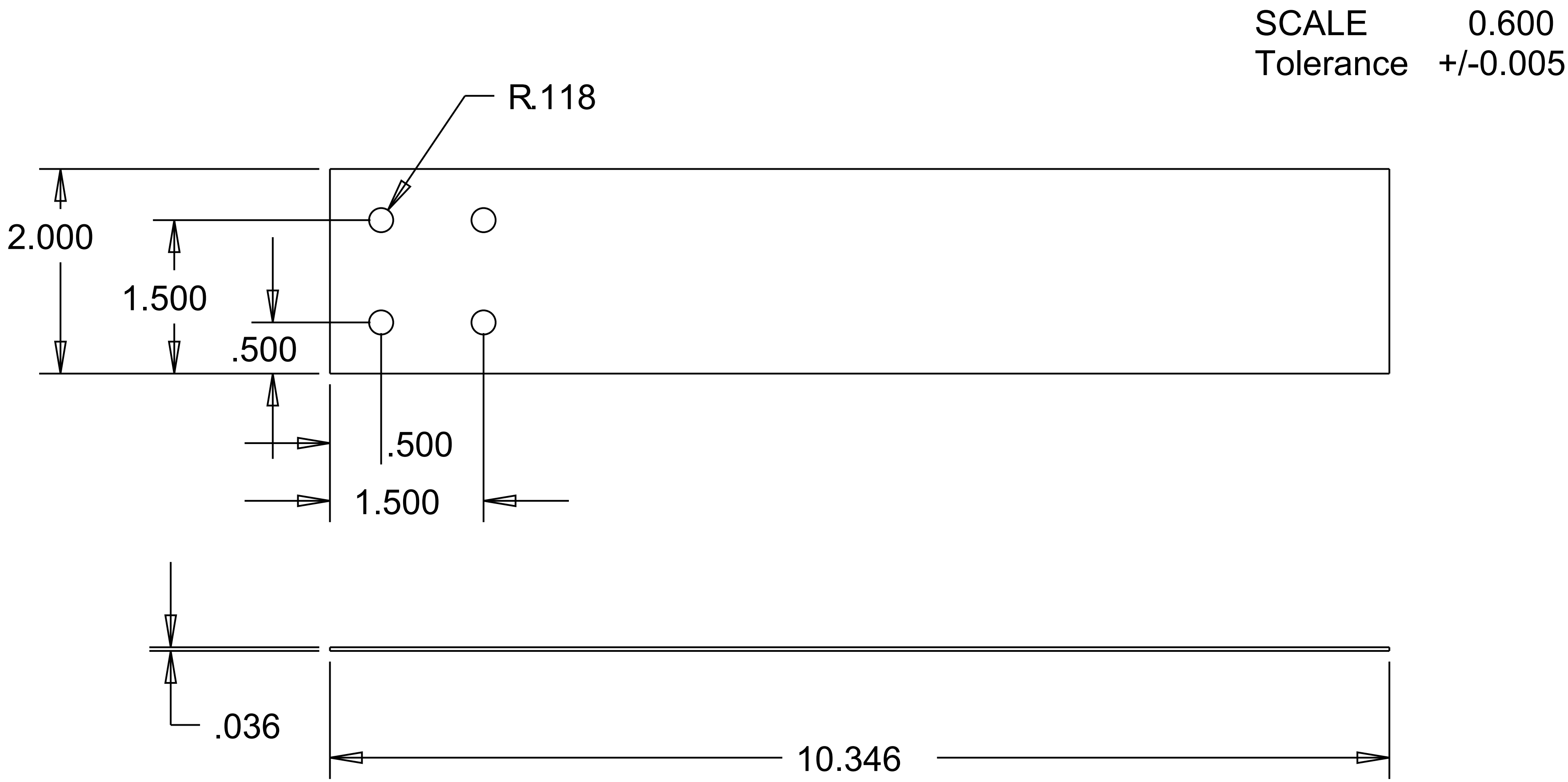
Model Housing	
SHEET #	004
LAST REVISION	04/07/09
REVISION #	001
DRAWING #	SD-P-0020

Gear Cover Assm
Cummins Team 7



Gear Cover Assm	
Cummins Group 7	

Long Cantilever	
SHEET #	001
LAST REVISION	11/21/08
REVISION #	001
DRAWING #	SD-M-001

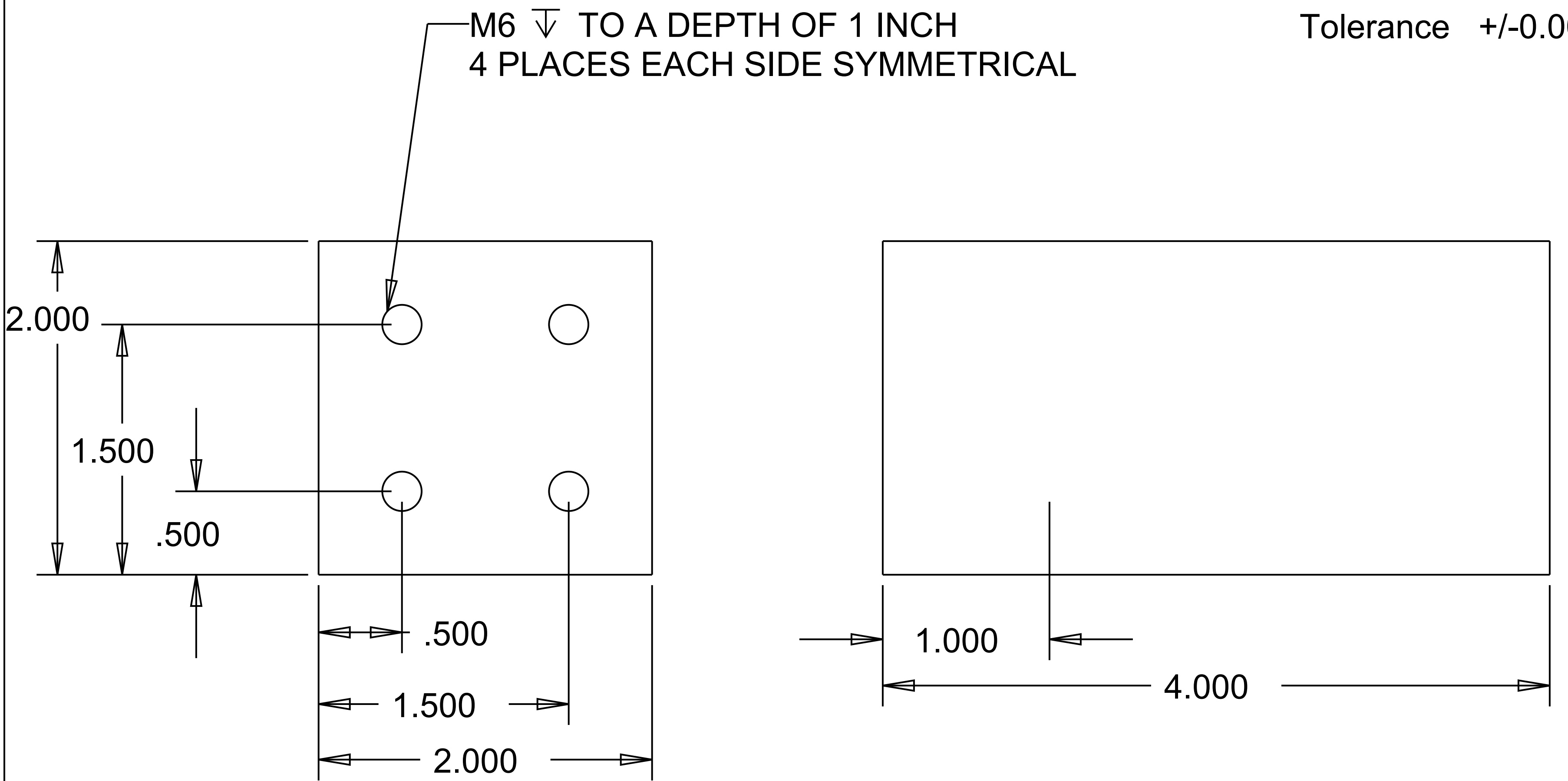


Short Cantilever	
SHEET #	001
LAST REVISION	11/21/08
REVISION #	001
DRAWING #	SD-M-002

Gear Cover Assm

Cummins Group 7

SCALE 1.000
Tolerance +/-0.005

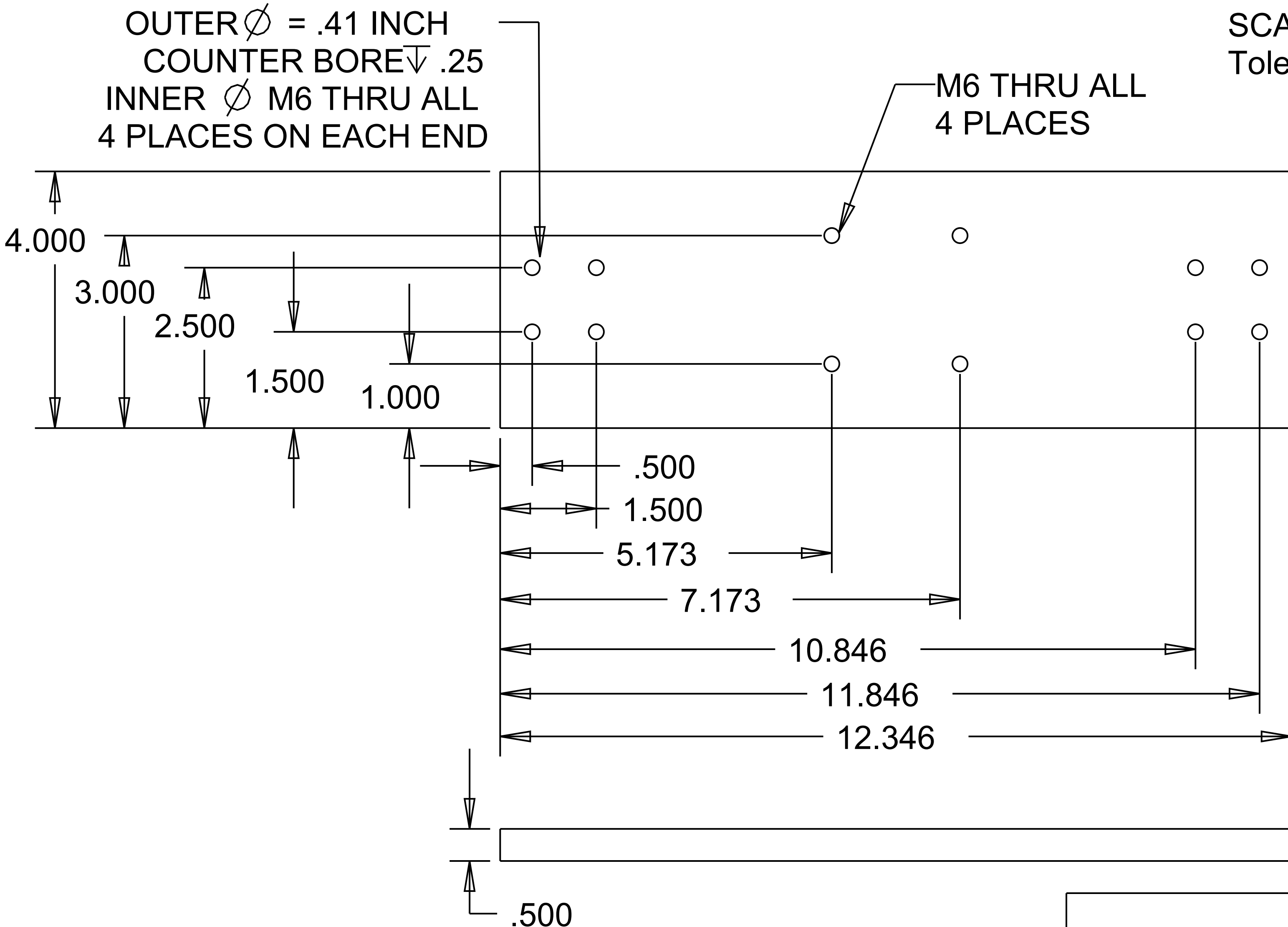


SUPPORT	
SHEET #	002
LAST REVISION	12/2/08
REVISION #	001
DRAWING #	SD-P-018

PZT TEST APP.

CUMMINS GROUP 7

SCALE 0.400
Tolerance +/-0.005



	Baseplate
SHEET #	001
LAST REVISION	04/07/09
REVISION #	001
DRAWING #	SD-P-019

PZT TEST APP.

CUMMINS GROUP 7