CHAPTER 7

EXPERIMENTAL INVESTIGATIONS ON PSOP-PCB ASSEMBLY SUBJECTED TO VIBRATION LOADS

7.1 INTRODUCTION

The earlier electronic devices such as DIP package was typically a large through-hole device with maximum lead count of 64 which is one of the main limitations of DIPs. A solution to this is the Pin Grid Array (PGA) which uses a two dimensional array of pins protruding from the bottom of the package and can have pin count of 200. The trend in PCB manufacturing was to increase density while decreasing the board area. Through-hole devices did not easily allow this to happen. During 1980’s, through-hole devices began to give way to a new packaging technology called Surface Mount Technology, or SMT. The leads from these packages mount directly to rectangular pads on the surface of the printed circuit boards. They did not require holes to be drilled into PWBs. As a result, the width of the leads could be smaller and the spacing between the leads (lead pitch) could be decreased. This allowed for a package with the same number of pins as a traditional through-hole device to be significantly smaller. Common surface mount devices are the Plastic Leaded Chip Carrier (PLCC) and Small Outline Integrated Circuits (SOIC) or Small Outline Packages (SOP). If the SOP body is made of plastic, it is called as PSOP. Other modern surface mount package having large number of I/O count is Quad Flat Pack (QFP).

This chapter presents the experimental results of PSOP-PCB assembly subjected to different vibration environments. The test vehicle as
shown in Figure 7.1 was constructed as per the JEDEC standard using five PSOP chips mounted on the PCB measuring 132 mm x 77 mm x 1.6 mm. The detailed construction of the PSOP along with dimensions is as shown in Figure 7.2.
7.2 SINE SWEEP TESTS ON PSOP–PCB ASSEMBLY

7.2.1 PCB Assembly Mounted on Plastic Spacers

The PCB assembly was mounted on an aluminum fixture using plastic spacers placed at the four corners (Figure 7.3). The natural frequencies of the PSOP-PCB assembly were determined by conducting a sine sweep test trial at 0.5G in the frequency range 20–800 Hz and the test results revealed that, none of the natural frequencies of the PCB assembly were below 100 Hz. Therefore the electronic assembly was subjected to harmonic excitation with an input acceleration of 0.5G and swept in the frequency range 100–800 Hz at the rate of 1 octave per minute.

![Figure 7.3 PSOP-PCB assembly mounted on plastic spacers](image)

The response plot obtained from the sine swept test is as shown in Figure 7.4. The peak response acceleration of 55G is observed at about 370 Hz and the deflection of PCB assembly at this resonant frequency is 0.1 mm and the transmissibility ratio \( \left( \frac{G_{\text{out}}}{G_{\text{in}}} \right) \) is 110. The transmissibility plot of the PCB assembly due to 0.5G input acceleration is as shown in Figure 7.5. Using the procedure explained in section 4.3 (chapter 4), the damping ratio for this arrangement is calculated and it is found to be 0.011.
Figure 7.4 Response of the PCB mounted on plastic spacers due to 0.5G input

Figure 7.5 Transmissibility plot of the PCB mounted on plastic spacers due to 0.5G input

Similarly, the sine-sweep tests were conducted on the PSOP-PCB assembly at an input acceleration of 0.75G, and 1G and the response plots are shown in Appendix 2.
7.2.2 PCB assembly mounted on rubber spacers

The transmissibility ratio of the PCB assembly mounted on plastic spacers was found to be 110 which lead to amplification of acceleration levels at resonant frequencies. In order to minimize the transmissibility ratio, the PSOP-PCB assembly was mounted on rubber spacers (Figure 7.6) instead of plastic spacers and the sine sweep tests were conducted as explained in the previous section.

![Figure 7.6 PCB assembly mounted on rubber spacers](image)

The frequency response plot obtained from the sine-sweep test due to 0.5G input acceleration is as shown in Figure 7.7. From the figure it is seen that, the peak acceleration level experienced by the PCB assembly is reduced to 30G (from 55G) and the deflection of PCB assembly at the first resonant frequency is found to be 0.06 mm. Thus, a reduction of 45% in peak acceleration and 40% reduction in displacement levels are obtained by using neoprene rubber spacers.
Figure 7.7  Response of PCB mounted on rubber spacers due to 0.5G input

The transmissibility plot of the PCB assembly due to 0.5G input acceleration is as shown in Figure 7.8, from which the transmissibility ratio at first resonant frequency is about 60 i.e., a reduction of 46% is achieved by mounting the PCB assembly on rubber spacers. The damping ratio calculated for this type of PCB mounting is found to be 0.018 i.e., there is an increase of 39% in the system damping.

Figure 7.8  Transmissibility plot of the PCB mounted on rubber spacers due to 0.5G input
7.2.3 PCB assembly mounted on rubber pads

To further reduce the transmissibility ratio and the displacement, the PCB assembly was mounted on rubber pads as shown in Figure 7.9. Sine swept test with an input acceleration of 0.5G was conducted on this setup.

The frequency response of the PSOP-PCB assembly due to 0.5G input sine-sweep test is shown in Figure 7.10. From the figure it is seen that, the dominant resonant frequency is at about 405 Hz and the corresponding acceleration level and displacement at this frequency are 15G and 0.02 mm respectively. Thus, by mounting the PSOP-PCB assembly on rubber pads the peak acceleration level is reduced by 50% and the displacement level by 67% when compared to the responses of the PCB assembly mounted on rubber spacers.
Figure 7.10  Response of the PCB mounted on rubber pads due to 0.5G input

The transmissibility ratio of the PSOP-PCB assembly mounted on rubber pads is found to be 30 i.e., the rubber pads reduced the transmissibility ratio by 50% compared to the PCB assembly mounted on rubber spacers. The transmissibility plot is shown in Figure 7.11. The damping ratio calculated for this type of PCB mounting is found to be 0.022.

Figure 7.11 Transmissibility plot of the PCB mounted on rubber pads due to 0.5G input
7.2.4 Comparison of Sine-Sweep Tests

Table 7.1 below shows the natural frequencies of the PCB assembly for the three mounting methods. The lower natural frequencies remain almost same for all the cases, whereas the fifth mode frequency is reduced to 340 Hz when mounted on rubber spacer. Similarly, the fifth mode frequency is increased to 405 Hz when the PCB is mounted on the rubber pads. The PCB assembly mounted with its longer edges resting on rubber pads will have higher natural frequency and also higher damping ratio, while reducing peak acceleration and displacement to a great extent.

Table 7.1 Natural Frequencies of the PCB assembly

<table>
<thead>
<tr>
<th>Mode Number</th>
<th>Modal frequency (Hz)</th>
<th>Plastic spacer</th>
<th>Rubber spacer</th>
<th>Rubber pad</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>110</td>
<td>120</td>
<td>110</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>130</td>
<td>140</td>
<td>140</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>180</td>
<td>170</td>
<td>175</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>230</td>
<td>230</td>
<td>230</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>370</td>
<td>340</td>
<td>405</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>750</td>
<td>710</td>
<td>740</td>
<td></td>
</tr>
</tbody>
</table>

Figure 7.12 shows the variation of peak acceleration levels due to different mounting methods of the PCB assembly (at 0.5G input). From the Figure 7.12 it may be observed that, the peak acceleration level is reduced to about 45% when PCB is mounted on rubber spacers and it is further reduced by 73% when mounted on rubber pads (compared to responses of PCB assembly mounted on plastic spacers). Thus, by using rubber spacers and rubber pads the peak acceleration levels at resonant frequencies are reduced by considerable amounts.
Figure 7.12 Comparison of acceleration responses

Figure 7.13 illustrates the variation of transmissibility ratio for different PCB mounting methods. From the figure it is evident that, the transmissibility ratio is reduced by 45% when the PCB is mounted on rubber spacer and by 86% when it is mounted on rubber pads. Thus, by using the rubber spacers and pads, the transmissibility ratios are reduced to a great extent.

Figure 7.13 Comparison of transmissibility ratios
The displacement plots for the three clamping methods is shown in Figure 7.14. From this figure it is observed that the rubber spacer will cushion the PCB assembly and reduce the displacement by 40% compared to plastic spacers. Rubber pads reduced the displacement level of the PCB assembly by 67%. Thus, the rubber spacers and pads may be effectively used to reduce dynamic displacement of PCB assemblies in sinusoidal vibration environments.

![Displacement plots with an input acceleration of 0.5G](image)

**Figure 7.14 Comparison of displacement responses**

The summary of the sine sweep tests conducted on PSOP-PCB assembly using different types of spacers is tabulated in Table 7.2. From Table 7.2 it is evident that, the rubber spacers and rubber pads reduced the dynamic displacement, peak acceleration and transmissibility ratio by a considerable as shown in the brackets in the table.
Table 7.2 Comparison of Sinusoidal test results

<table>
<thead>
<tr>
<th>PCB mounting method</th>
<th>Resonant frequency (Hz)</th>
<th>Displacement (mm)</th>
<th>Peak acceleration (G)</th>
<th>Transmissibility ratio, $Q$ ($G_{out}/G_{in}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plastic spacers</td>
<td>370</td>
<td>0.1</td>
<td>55</td>
<td>110</td>
</tr>
<tr>
<td>Rubber spacers</td>
<td>340</td>
<td>0.06 (40%)*</td>
<td>30 (45%)*</td>
<td>60 (45%)*</td>
</tr>
<tr>
<td>Rubber pads</td>
<td>405</td>
<td>0.02 (67%)#</td>
<td>15 (50%)#</td>
<td>30 (50%)#</td>
</tr>
</tbody>
</table>

* figures within the bracket indicate percent of reduction with respect to plastic spacer data
# figures within the bracket indicate percent of reduction with respect to plastic spacer data

7.3 RANDOM VIBRATION TESTS ON PSOP-PCB ASSEMBLY

7.3.1 PCB Assembly Mounted on Plastic Spacers

The random vibration tests conducted on PSOP-PCB assembly are presented in this section. The test vehicle used for the random vibration tests is as shown in Figure 7.1. The input acceleration power spectral density profile was programmed as per JEDEC’s level ‘D’ using random vibration test software (Figure 7.15). The split up of PSD magnitudes corresponding to level ‘D’ is tabulated in Table 5.1. The PCB assembly is excited in Z direction using the test setup as shown in Figure 5.4 (Chapter 5).
The PCB assembly response recorded during the test is as shown in Figure 7.16. The peak acceleration PSD level of 10 $G^2/Hz$ is observed at the resonant frequency of 399 Hz and the $G_{rms}$ level experienced by the PCB assembly is 16.82 (area under the response curve). The RMS displacement at the centre of the PCB is calculated using Equation (5.1), and it is about 0.03 mm.

Figure 7.15 Random vibration input test profile (level D of JEDEC)

Figure 7.16 Response of the PCB mounted on plastic spacers
The transmissibility ratio plot obtained is as shown in Figure 7.17. Again from this figure it is evident that, the maximum transmissibility ratio of about 41 is seen at the resonant frequency of 399 Hz. By using rubber spacers and rubber pads the transmissibility ratio and PSD levels are minimized and it is shown with the help of experimental results in sections 7.3.2 and 7.3.3.

![Transmissibility Plot](image)

**Figure 7.17 Transmissibility plot of the PCB mounted on plastic spacers**

### 7.3.2 PCB Assembly Mounted on Rubber Spacers

In previous section, it was observed that, the output PSD level and $G_{rms}$ levels were at the maximum when PCB assembly was mounted on plastic spacers. Therefore, to reduce the response PSD and $G_{rms}$ levels, the PCB was mounted on rubber spacers and the experiments were repeated using the same input PSD profile. The response PSD plot is as shown in Figure 7.18, from which the maximum PSD level of $4 \, G^2/Hz$ is observed at first resonant frequency and the $G_{rms}$ level is found to be 9.79. The RMS displacement at the PCB centre is found to be 0.02 mm. Thus, by using rubber spacers, PSD and $G_{rms}$ levels are reduced by 60% and 42% respectively. Similarly, the RMS displacement of PCB assembly is reduced by 33% by mounting it on rubber spacers.
Figure 7.18 Response of the PCB mounted on rubber spacers

The transmissibility plot of the PCB mounted on rubber spacers is shown in Figure 7.19. From this figure it is observed that, the transmissibility ratio at 375 Hz is about 32 i.e., a reduction of about 24% is achieved when compared to the transmissibility ratio when the PCB is mounted on plastic spacers.

Figure 7.19 Transmissibility plot of the PCB mounted on rubber spacers
7.3.3 PCB Assembly Mounted on Rubber Pads

To check the influence of rubber pads on the dynamic response of PCBs in the random vibration environment, the PSOP-PCB assembly was mounted on rubber pads as shown in Figure 7.9. The PCB response to the specified random vibration input is as shown in Figure 7.20, from which the following points are noticed. The dominant resonant frequency is found to be more than 500 Hz while the PSD amplitude at the frequency of 500 Hz is reduced to about 0.08 $G^2/Hz$. Similarly, the $G_{rms}$ value is also reduced to 2.83. Thus, the PSD amplitude and $G_{rms}$ levels are respectively reduced by 98% and 71% when compared to responses of PCB mounted on rubber spacers.

![Figure 7.20 Response of the PCB mounted on rubber pads](image)

The transmissibility plot of the PCB assembly mounted on rubber pads is as shown in Figure 7.21, from which it is observed that, the transmissibility ratio is also reduced by 25% (compared to rubber spacers).
The summary of the random vibration test results of the all the three mounting methods is given in Table 7.3.

Table 7.3 Summary of Random vibration test results on PSOP-PCB assembly

<table>
<thead>
<tr>
<th>PCB mounting method</th>
<th>$G_{rms}$</th>
<th>PSD ($G^2$/Hz)</th>
<th>PCB displacement, $Z_{rms}$ (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plastic spacer</td>
<td>16.82</td>
<td>10</td>
<td>0.03</td>
</tr>
<tr>
<td>Rubber spacer</td>
<td>9.79 (42)*</td>
<td>4 (60)*</td>
<td>0.02 (33)*</td>
</tr>
<tr>
<td>Rubber pads</td>
<td>2.83 (83)#</td>
<td>0.08 (99)#</td>
<td>0.003 (90)#</td>
</tr>
</tbody>
</table>

* figures within the bracket indicate percent of reduction with respect to plastic spacer data
# figures within the bracket indicate percent of reduction with respect to plastic spacer data

From Table 7.3 it may be noticed that the use of rubber spacers and rubber pads as vibration isolators in a random vibration environment are effective and reduce the PSD levels by considerable magnitudes.
7.4 MECHANICAL SHOCK TESTS ON PSOP-PCB ASSEMBLY

Many times, the electronic equipment will experience light to moderate mechanical shock loads during handling and transportation. The objective of conducting mechanical shock tests on electronic assemblies is to assess the survivability and to improve the design such that the electronic equipment is rugged enough to sustain severe mechanical shocks. The test vehicle used for conducting mechanical shock load is same as the one which is used for sinusoidal and random vibration tests.

7.4.1 Mechanical Shock Tests with PCB Assembly Mounted on Plastic Spacers

The test vehicle is subjected a half sine pulse having peak acceleration of 20G, 25G and 30G. The half sine input pulse having 5 milliseconds pulse duration and 800 milliseconds as delay between two pulses was programmed using shock software and a typical pulse is shown in Figure 7.22.

![Figure 7.22 A typical half sine pulse programmed using shock software](image-url)
The response of the PCB to an input shock pulse of 20G peak acceleration is shown in Figure 7.23. From this figure it is observed that, the PCB will rattle more before coming to rest. In other words, plastic spacers will absorb minimum input energy and most part of it is transferred to the PCB, which will have sufficient energy to oscillate for longer time i.e. for about 260 milliseconds. Hence, the input shock is amplified and the peak output acceleration at the centre of PCB is found to be 30.32G (Figure 7.23). Similarly, the peak acceleration responses due to an input acceleration of 25G and 30G are 34.36G and 38.32G respectively and the response graphs are shown in Appendix 2.

![Figure 7.23 Response of PCB mounted on plastic spacers due to 20G input](image)

7.4.2 Mechanical Shock Tests with PCB Mounted on Rubber Spacers

The mechanical shock tests were conducted with an input half sine shock pulse at 20G, 25G and 30G acceleration levels by mounting the PSOP-PCB assembly on rubber spacers. The response acceleration of 21.65G is observed due to an input shock load of 20G as shown in Figure 7.24. From this figure it is observed that, the response dies more quickly compared to the
response of PCB when mounted on plastic spacers. In other words, rubber spacers will absorb significant portion of the input energy and there is less energy available for the PCB and the vibrations will take less time to decay i.e., about 180 milliseconds. Similarly, the responses due to 25G and 30G shock loads are shown in Appendix 2. The results of the two tests are tabulated in Table 7.4 for comparison.

Figure 7.24  Response of PCB mounted on rubber spacers due to 20G input

7.4.3  Mechanical Shock Tests with PCB Assembly Mounted on Rubber Pads

The PCB assembly is mounted on two rectangular rubber pads as shown in Figure 7.9. The longer sides of the PCB are resting on rubber pads. Now the PCB assembly is subjected to mechanical shock loads with an input acceleration level of 20G, 25G, and 30G. The response of PCB due to a shock input of 20G is shown in Figure 7.25. From this figure it is seen that, the output acceleration is about 19G which is less than the input acceleration, which means the transmissibility ratio is less than one. The response will take about 140 milliseconds to die out completely, which is an indication of
increase in the system damping. Similar trend is observed at higher input loads also. The shock responses of the PCB assembly due to $25G$ and $30G$ input loads are shown in Appendix 2 and the summary of shock test results is shown in Table 7.4.

![Response of PCB mounted on rubber pads due to 20G input](image)

**Figure 7.25** Response of PCB mounted on rubber pads due to to $20G$ input

**Table 7.4 Comparison of shock tests**

<table>
<thead>
<tr>
<th>Input Shock ($G$)</th>
<th>Plastic spacers</th>
<th>Rubber spacers</th>
<th>Rubber pads</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>30.32</td>
<td>21.65 (29)*</td>
<td>19.11 (37)*</td>
</tr>
<tr>
<td>25</td>
<td>34.36</td>
<td>27.49 (20)</td>
<td>22.1 (36)</td>
</tr>
<tr>
<td>30</td>
<td>38.32</td>
<td>34.12 (11)</td>
<td>25.82 (32)</td>
</tr>
</tbody>
</table>

* figures in bracket indicate percentage of reduction with respect to plastic spacers

From Table 7.4 it may seen that, the peak acceleration experienced by the PCB assembly is reduced by 29% and 37% (due to 20G input) when it
is mounted on rubber spacers and rubber pads respectively. Also, from Table 7.4 it can be noticed that, the rubber spacers are found to be less effective at higher shock loads.

Due to reduction in the peak accelerations levels experienced by the PCB assembly, the corresponding deflection and stress magnitudes will reduce improving the life of the electronic system.

7.5 ANSYS SIMULATION

7.5.1 Sinusoidal Vibration Simulation

The computational model of PSOP-PCB assembly is created in ANSYS to simulate the sinusoidal vibration tests conducted with plastic spacers. The PCB assembly is constrained at the holes and an input load of 0.5G is applied to the PCB assembly. The displacement plot obtained from simulation is as shown in Figure 7.26. From this figure it is evident that the displacement at the PCB centre is 0.0993 mm which is close to the experimental results (0.1 mm).

Figure 7.26 Displacement plot of PCB mounted on plastic spacers
Similarly, Figure 7.27 shows the displacement plot of the PSOP-PCB assembly mounted on rubber spacers. From this figure it is observed that, the displacement at the centre of the PCB is about 0.0466 mm again which is close to the displacement value obtained from the experiment.

![Displacement plot of PCB mounted on rubber spacers](image)

**Figure 7.27 Displacement plot of PCB mounted on rubber spacers**

### 7.5.2 Random Vibration Test Simulations

Similarly, ANSYS simulation was done to simulate the random vibration experiments conducted on PSOP-PCB assembly mounted on plastic spacers and subjected to random input load (Figure 7.15). The input PSD is applied at the constrained nodal degrees of freedom of the four corner holes. A uniform damping ratio of 0.011 was used during the analysis. The $1\sigma$ displacement plot obtained from the spectrum analysis is as shown in Figure 7.28 and the RMS displacement value of 0.0285 mm is found at the PCB centre. This value is close to the experimental value of 0.03 mm.
Figure 7.28 $1\sigma$ RMS displacement – PCB mounted on plastic spacers

Figure 7.29 shows the $1\sigma$ RMS acceleration plot of the PCB assembly, from which it is evident that the package located at the centre of PCB will experience an acceleration of $15.9G_{\text{rms}}$, which is nearer to the $G_{\text{rms}}$ value of 16.82 obtained from experiment (Figure. 7.16). Packages away from the centre of the PCB will experience minimum acceleration magnitudes.

Figure 7.29 $1\sigma$ RMS acceleration-PCB mounted on plastic spacers
Figure 7.30 shows the PSD response captured at the centre of the PCB assembly. From this figure, the PSD level at natural frequency of 397 Hz is found to be 10, which is equal to the PSD value obtained from the experimental random vibration test.

![Figure 7.30 PSD response at the PCB centre](image)

Spectrum analysis results for the PSOP-PCB assembly mounted on rubber spacers are shown in Figures 7.31 and 7.32. Figure 7.31 shows the $1\sigma$ RMS displacement of the PCB when it is mounted on rubber spacers. Similarly, Figure 7.32 shows $1\sigma$ RMS acceleration when the PCB is mounted on rubber spacers.

Results obtained from spectrum analysis results (simulating PCB mounted on rubber spacers) are close to the experimental results obtained by mounting PCB assembly on rubber spacers.
Figure 7.31 $1\sigma$ RMS displacement – PCB mounted on rubber spacers

Figure 7.32 $1\sigma$ RMS acceleration-PCB mounted on rubber spacers

The experimental and simulation results of sine sweep and random vibration tests are tabulated in Table 7.5 for comparison.
Table 7.5 Comparison of experimental and ANSYS results

<table>
<thead>
<tr>
<th>Vibration Tests</th>
<th>Parameters</th>
<th>Experimental</th>
<th>ANSYS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Plastic spacers</td>
<td>Rubber spacers</td>
</tr>
<tr>
<td>Sine Sweep</td>
<td>Displacement (mm)</td>
<td>0.1</td>
<td>0.06</td>
</tr>
<tr>
<td>Random</td>
<td>$G_{rms}$</td>
<td>16.82</td>
<td>9.79</td>
</tr>
<tr>
<td></td>
<td>$Z_{rms}$ (mm)</td>
<td>0.03</td>
<td>0.02</td>
</tr>
</tbody>
</table>

From Table 7.5 it may be seen that the ANSYS simulation results are in close agreement with the experimental results.

7.6 RESULTS AND DISCUSSIONS

The PSOP-PCB assembly was subjected to sinusoidal, random and mechanical shock vibration loads. In this chapter, the effectiveness of rubber spacers and rubber pads as vibration and shock isolators in all the three vibration environments are investigated by experimental procedures.

**Sinusoidal Tests:** The PCB assembly was subjected to an input acceleration of 0.5G for all the three mounting methods. The experimental results reveal that, the PCB mounted on plastic spacers experienced a deflection of 0.1 mm, output acceleration of 55G and a transmissibility ratio of 110 (at first resonant frequency). When the PCB assembly was mounted on rubber spacers and subjected to same input acceleration of 0.5G, the deflection and peak acceleration levels were reduced by 40% (0.06 mm) and 46% (30G) respectively. Also, the transmissibility ratio was reduced by 46% . Similarly, when the PCB was mounted on rubber pads, the PCB displacement
was found to be 0.02 mm, and peak acceleration level at 15G. The transmissibility ratio is found to be 30 for this type of mounting. From Table 7.2 it is evident that, the rubber spacers and rubber pads have effectively reduced the peak acceleration levels, displacements and transmissibility ratios.

**Random Vibration Tests:** The random vibration test results conducted on PSOP-PCB assembly showed that, the rubber spacers and the rubber pads can reduce the displacement and $G_{rms}$ levels of the assembly. From Table 7.3 it is evident that the PCB assembly which is mounted on rubber spacers experienced 0.03 mm displacement, 9.79 $G_{rms}$ and a PSD level of 4 $G^2/Hz$. Similarly, the PCB mounted on rubber pads experienced a deflection of 0.003mm, $G_{rms}$ level of 2.83 and a PSD level of 0.08 $G^2/Hz$. Therefore, the rubber spacers and pads are proved to be effective in reducing the vibration amplitudes due to random input loads.

**Mechanical Shock Tests:** The suitability of rubber spacers and pads as sock isolators in a shock environment was investigated using mechanical shock tests on PSOP-PCB assembly. From Table 7.4 it is evident that the peak accelerations experienced by the PCB assembly was reduced by about 29% when mounted on rubber spacers and by 37% when mounted on rubber pads (compared to response of PCB mounted on plastic spacers at 20G input). Thus, rubber spacers and pads will absorb significant portion of the input energy and transmit little or no energy to the PCB and reduce the PCB deflections to a great extent.