OMAP35x Torpedo SOM Retention Testing

White Paper 439

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Revision History

REV	EDITOR	DESCRIPTION	APPROVAL	DATE
A	NWR, JCA	-Initial release	NJK	05/07/10
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1 Introduction

This white paper describes testing procedures and results that were conducted to understand the connection strength of the OMAP35x Torpedo SOM. When considering what product operating conditions might cause the OMAP35x Torpedo SOM to disconnect from the baseboard, three scenarios come to mind. One, the SOM can disconnect due to something pulling, hooking, or grabbing it. Two, the SOM can disconnect as result of vibration. Three, the SOM can disconnect from the shock of a drop or similar movement. To check the limits for each of these scenarios, three tests were performed: an extraction force test, vibration halt test, and drop test.

2 Extraction Force Test

2.1 Overview

2.1.1 Background

The OMAP35x Torpedo SOM's small connectors make it especially vulnerable to disconnection. When analyzing the different causes of disconnection, the first set of useful data is the force needed to pull the SOM straight off its baseboard at 90 degrees. This data gives a baseline for the connection strength. The amount of force required to disconnect the SOM can be generalized by the user when connecting and disconnecting the SOM from the baseboard during development. If the SOM is not enclosed in housing, it may also be susceptible to objects hooking or grabbing its edges. Therefore, knowledge of the extraction force can also help forecast whether or not a user should be concerned about possible disconnection.

2.1.2 Environment

This extraction force test was performed in Logic PD's mechanical shop under a normal room temperature between 68°F and 77°F.

2.1.3 Test Setup Diagram

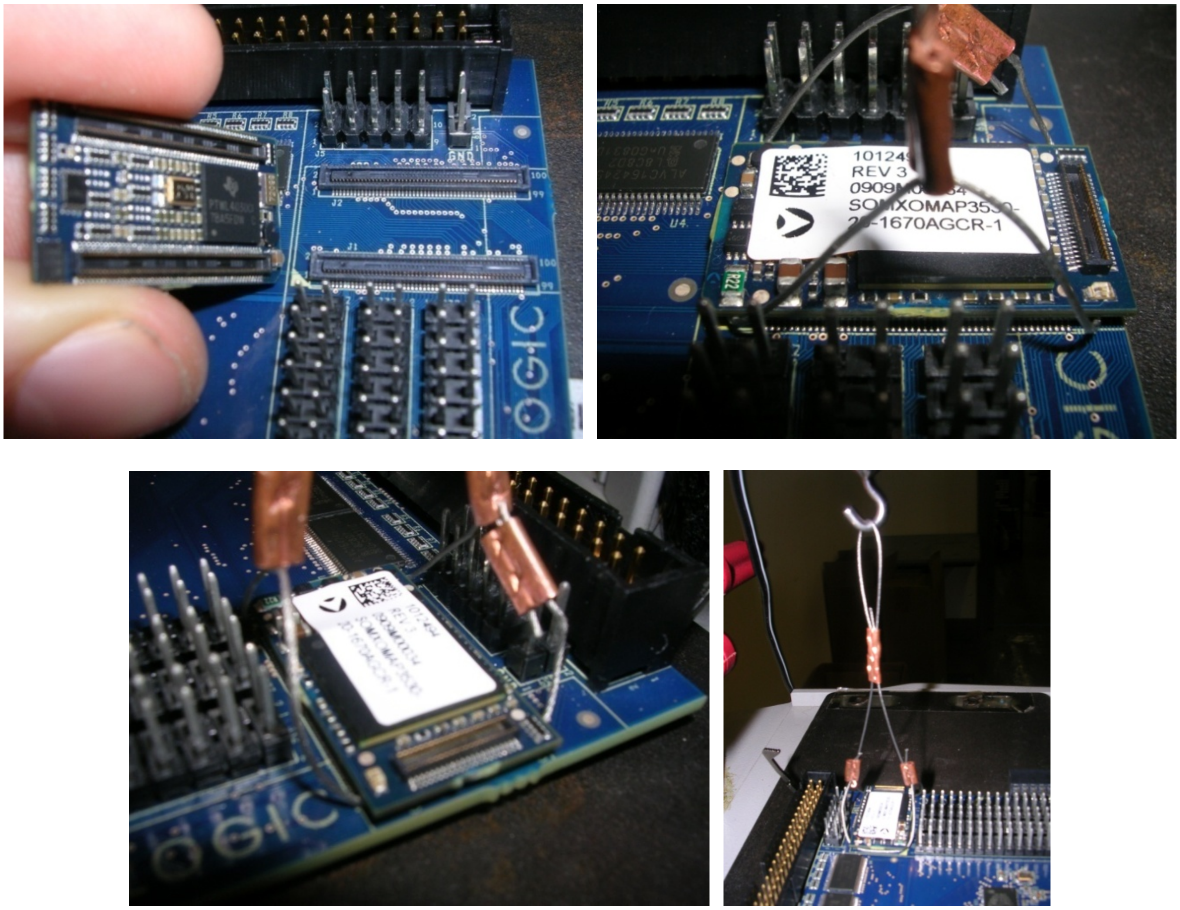

Figure 2.1: Extraction Force Test Harness

Figure 2.2: Force Gauge

2.1.4 Test Setup Description

As seen in Figure 2.1 and Figure 2.2 above, the setup utilized a thin steel cable fabricated to loop around the body of the OMAP35x Torpedo SOM. The harness then connected to the electronic force gauge. Once the baseboard was firmly secured to the fixture, the force gauge was gradually raised until the SOM disconnected.

2.2 Required Equipment

2.2.1 General Supplies

- OMAP35x Torpedo SOM units (5x)
- Torpedo Launcher Baseboard
- Steel cable harness

2.2.2 Measurement Equipment

- Dillon Quantrol force gauge—110 lb maximum, 0.03 lb resolution
- Vertical tension tester—Dillon TC^2 Tension Compression Cyclic

2.3 Test Procedure

2.3.1 Test Setup

As preparation for this test, the following steps were executed in succession:

- Built a thin cable harness to loop around the corners of the OMAP35x Torpedo SOM with another smaller loop on the opposite end to attach to the force gauge.
- Replaced the plunger on the force gauge with a hook attachment.

2.3.2 Test Steps

The following subtests were performed and the results were recorded in the action log:

1. Connected the OMAP35x Torpedo SOM to the baseboard.
2. Looped the cable harness around the edges of the OMAP35x Torpedo SOM.
3. Attached the opposite loop on the harness to the force gauge.
4. Set the force gauge to display the maximum force in a single cycle.
5. Set the tension tester to its slowest speed of 0.5 in/min in the vertical direction and set to single cycle.
6. Secured the baseboard to the fixture and ran a single cycle until the OMAP35x Torpedo SOM disconnected. Recorded the maximum force.
7. Repeated each of the steps 30 times, as this is the maximum rated number of cycles for the connectors.

2.4 Results

2.4.1 Data Results

The test procedure described in Section 2.3 was performed on five OMAP35x Torpedo SOMs and corresponding baseboards. At the time this document was created, Logic PD's OMAP35x Torpedo SOM was new and in transition to manufacturing, which made acquiring new units difficult. Therefore, the test results reflect a small sample base. A small sample base is acceptable for these tests since exact values will not be used to conclude whether or not a retention system is needed. In most cases, if there is any question about whether or not the OMAP35x Torpedo SOM will disconnect, a retention system should be used.

It was important to get OMAP35x Torpedo SOMs directly from the manufacturing line in order to ensure the connectors had never been previously connected. This assured that the results simulated an OMAP35x Torpedo SOM as used in a customer's end product. Table 2.1 shows the extraction forces measured in pounds.

Table 2.1: Extraction Force Results

Run #	Unit 1	Unit 2	Unit 3	Unit 4	Unit 5	Average
1	9.76	10.42	9.89	9.68	8.89	9.73
2	8.13	7.67	9.41	7.42	5.68	7.66
3	8.81	8.44	8.09	6.72	5.62	7.54
4	7.76	7.56	7.36	5.88	5.95	6.90
5	7.89	7.49	6.83	5.62	4.91	6.55
6	7.18	7.56	6.54	5.03	4.41	6.14
7	7.73	7.29	6.37	4.96	4.89	6.25
8	6.21	6.21	5.93	5.09	4.49	5.59
9	7.20	6.37	6.95	6.30	4.80	6.32
10	6.70	5.93	5.86	5.15	4.95	5.72
11	7.47	6.83	6.10	5.86	4.92	6.24
12	6.85	6.41	5.51	5.46	5.72	5.99
13	6.81	6.56	6.04	4.62	4.23	5.65
14	6.21	6.72	5.64	4.91	4.73	5.64
15	6.52	6.26	5.37	5.72	4.17	5.61
16	5.79	5.84	5.00	5.70	4.97	5.46
17	6.08	6.81	5.37	6.21	5.42	5.98
18	5.93	6.30	5.53	5.32	4.51	5.52
19	5.90	7.23	5.26	5.66	4.93	5.80
20	5.86	6.23	5.70	5.64	5.91	5.87
21	6.08	6.39	5.95	4.95	4.38	5.55
22	6.17	6.85	5.42	5.04	4.69	5.63
23	5.70	6.61	5.00	5.71	5.26	5.66
24	5.24	6.34	5.07	5.02	4.12	5.16
25	6.59	5.97	5.35	5.48	4.68	5.61
26	6.30	7.05	5.46	4.68	4.34	5.57
27	5.86	7.12	5.36	4.73	5.32	5.68
28	6.59	6.48	5.44	4.53	4.89	5.59
29	6.50	6.51	5.68	5.35	5.01	5.81
30	6.28	5.75	5.48	5.60	4.92	5.61

As seen in the table, the force needed to disconnect the OMAP35x Torpedo SOM on the first cycle was approximately 10 pounds. After the maximum rated number of insertion and extraction cycles (30) was completed, this force was reduced to approximately 6 pounds. These figures are the nominal values reported if a customer is interested in the force needed to disconnect the

OMAP35x Torpedo SOM. Figure 2.3 shows a graph of the force needed to disconnect the OMAP35x Torpedo SOMs tested.

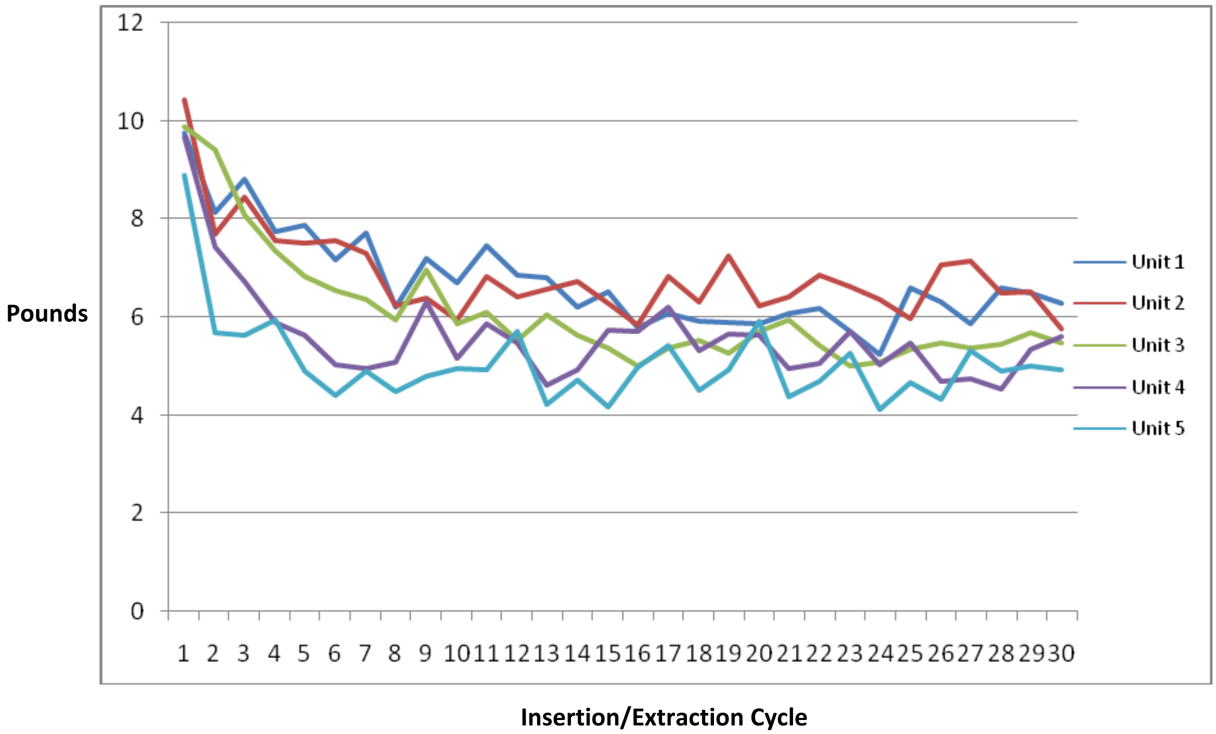

Figure 2.3: Extraction Force Graph

Since the connectors are rated for only 30 connect-disconnect cycles by the manufacturer, we are only interested in the data for 1 to 30 cycles. After 30 cycles, it appears the force plateaus at approximately 5 pounds. It is also worthy to note the spikes in the graph. These are due to the OMAP35x Torpedo SOM connectors being pulled out at a slight angle. This can cause the corners to experience extra friction and stick. While this results in small spikes in the data, it never adds more than 1 pound of extra force. Logic PD is concerned only about characterizing the OMAP35x Torpedo SOM and obtaining a general idea of when it will disconnect, so this extra pound is of no consequence. The downward spikes in the data correspond to the OMAP35x Torpedo SOM not being completely inserted. Since they are also within 1 pound, there is no need to be concerned with this information either.

With this extraction data, general trend lines can be formed that characterize the behavior of the OMAP35x Torpedo SOM's connection to the baseboard throughout its product lifecycle. Figure 2.4 shows trend lines based on a power fit. Notice how the force for each of the connections decrease markedly in the first 10 extractions, then it begins to plateau at around 5-6 pounds for the remaining extractions.

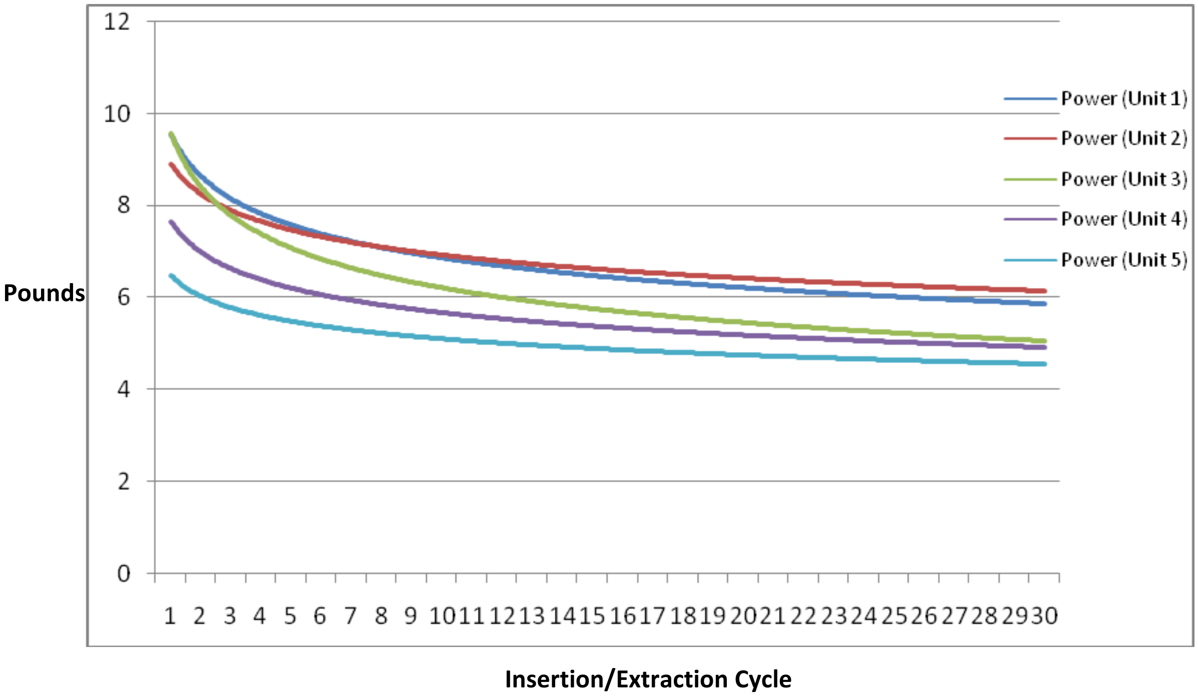

Figure 2.4: Extraction Force Trend Graph

2.5 Conclusions

The OMAP35x Torpedo SOM disconnects with the application of 5-10 pounds of force. This result shows that both Logic PD and customers need to be concerned about the OMAP35x Torpedo SOM disconnecting, since 10 pounds of force could be encountered in everyday use. This result initially drove the need for a retention system solution.

3 Vibration Test

3.1 Overview

3.1.1 Background

Vibration testing is the shaking of the product to test how it withstands its environment. This is important for determining how the product reacts to real-life situations like shipping or being used in a moving vehicle. With the OMAP35x Torpedo SOM, the concern was that the vibration would cause it to disconnect. Therefore, a highly accelerated life test (HALT) was performed.

A HALT test methodology is usually used to identify a flaw in the design during its development. Reliable results can usually be achieved from a very limited number of samples. This test is performed by slowly increasing the amount of stress put onto the sample until failure. By observing what component failed first, the weakest part of the device can be determined. For the OMAP35x Torpedo SOM, the amplitude and frequency of vibration will be increased until the connectors fail. This will happen when the connectors no longer retain enough tightness to remain connected and will result in the OMAP35x Torpedo SOM disconnecting from the baseboard. The level of vibration applied can then be recorded. This vibration test will also be useful in examining the smaller components like the processor and SDRAM on the OMAP35x Torpedo SOM's circuit board.

3.1.2 Environment

This vibration test was performed on Logic PD's manufacturing floor under a normal room temperature between 68°F and 77°F.

3.1.3 Test Setup Diagram

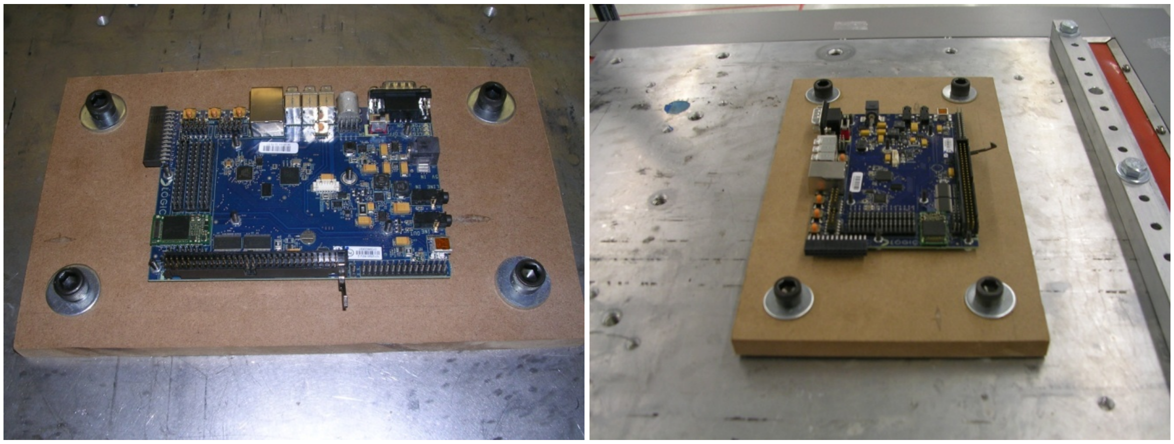

Figure 3.1: Vibration Test Fixture

Figure 3.2: Vibration Table

3.1.4 Test Setup Description

The test fixture is made of medium-density fiberboard. Holes were drilled through the fiberboard, and the Torpedo Launcher Baseboard was secured to it. The fiberboard and baseboard were then secured onto the vibration table with 5/8" bolts.

3.2 Required Equipment

3.2.1 General Supplies

- OMAP35x Torpedo SOM
- Torpedo Launcher Baseboard
- Medium-density fiberboard
- 5/8” x 1/2” socket head cap screws (4x)
- 2-56 x 1/2” socket head cap screws (7x)
- 2-56 hex nuts (7x)
- 2-56 x 1/8” nylon standoff

- Qualmark OVTT vibration table
  - 3-axis, 6-degree-of-freedom HALT testing table, air actuated, 18" x 18" table size

3.2.2 Measurement Equipment

- Allen-Bradley Panel View 300 (encompassed in vibration table)
- Accelerometer

3.3 Test Procedure

3.3.1 Test Setup

As preparation for this test, the following tasks were completed:

- Cut medium-density fiberboard was cut to at least 15” x 8”. Cut four 5/8” clearance holes in a 6” x 6” grid.
- Set the Torpedo Launcher Baseboard on the fiberboard and marked the baseboard mounting holes. Drilled these holes out for a 2-56 clearance hole.
- Secured the baseboard to the fiberboard using 2-56 screws. Placed nylon standoffs between the baseboard and the fiberboard to minimize warp in the circuit board.
- Secured the fiberboard to the vibration table with 5/8” hex screws.
- Inserted the OMAP35x Torpedo SOM into the baseboard.

3.3.2 Test Steps

The following subtests were performed and the results were recorded in the action log:

1. After the board was secured, closed the lid on the vibration table.
2. Ran a stepped vibration HALT test in 5G intervals, 10 minutes at each interval. Vibration stepped up until the connectors failed.
3. Repeated this process four more times.

3.4 Results

3.4.1 Data Results

After running the stepped vibration test on the OMAP35x Torpedo SOMs and baseboards, the following results were recorded.

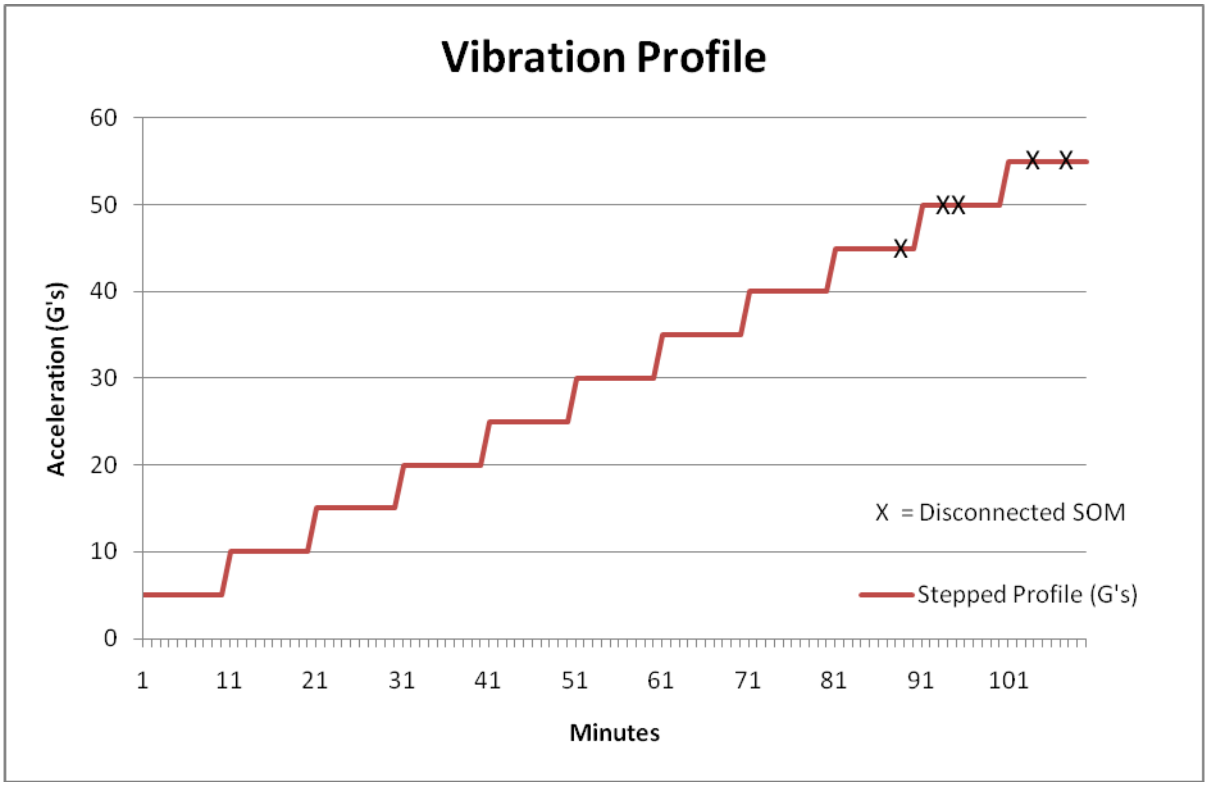

Figure 3.3: Stepped Vibration Results

As seen in Figure 3.3, the OMAP35x Torpedo SOM remained connected through 40 G for every unit. These results give a good estimate of the durability of the connectors during vibration.

3.5 Conclusions

The 40 G level of vibration that was reached was much higher than expected. This is most likely due to the OMAP35x Torpedo SOM's small mass of 1.95 grams. Because the SOM has such a small mass, the amount of force applied on the connectors remains low even at high levels of vibration. A 45 G level of vibration is comparable to a small explosion, so the OMAP35x Torpedo SOM should perform reliably through most vibration conditions.

4 Shock Test

4.1 Overview

4.1.1 Background

Portable electronic devices incorporate a large percentage of the latest technology. Having access to so many applications in the palm of your hand is revolutionizing people's day-to-day lives. One notable downside to all these portable electronics is gravity; it is fairly easy to lose your grip on a device. This is why the most common failures for handhelds come from drop impacts. A single drop can destroy housings, circuit boards, displays, connectors, etc. The OMAP35x Torpedo SOM must be mounted onto a baseboard in any product. Therefore, the main concern is the connection between these two boards. It takes 5-10 pounds of force to disconnect the connectors, but how high of a drop can the connectors withstand and what kind of acceleration does this correspond to? To test this, a constrained drop testing method was used rather than a free drop test.

In a constrained drop test, the object is clamped to a rigid body and dropped with vertical guides. This has many advantages: it allows the shock amplitude to be controlled by the drop height, its orientation is predetermined, and the drops are repeatable. The only disadvantage is that it does not allow the object to fall in its natural state; for example, when a cell phone is dropped, there is a very slim chance that it will fall without rotation.

4.1.2 Environment

This shock test was performed in Logic PD's mechanical engineering lab under a normal room temperature between 68°F and 77°F.

4.1.3 Test Setup Diagram

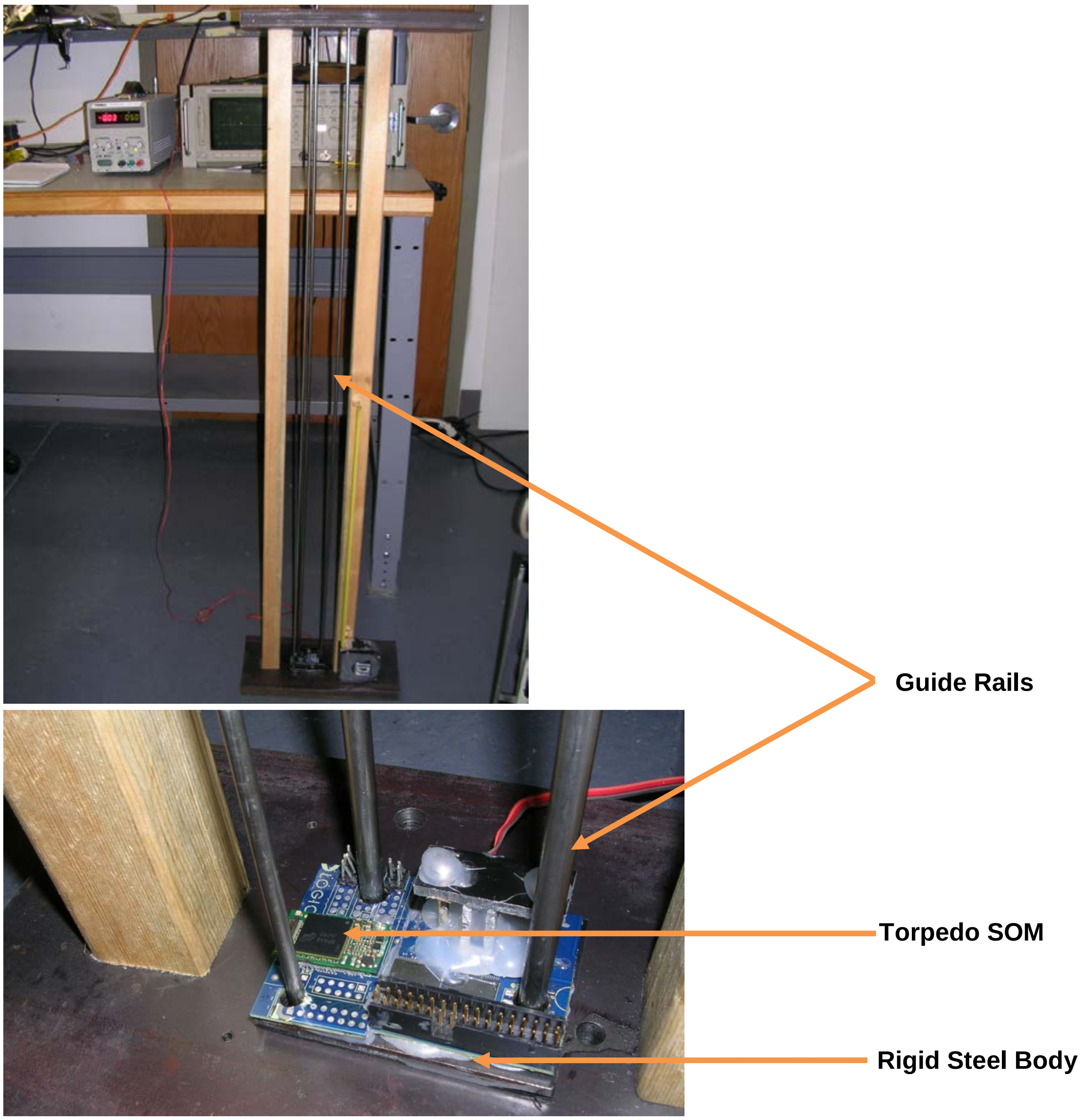

Figure 4.1: Torpedo Drop Fixture

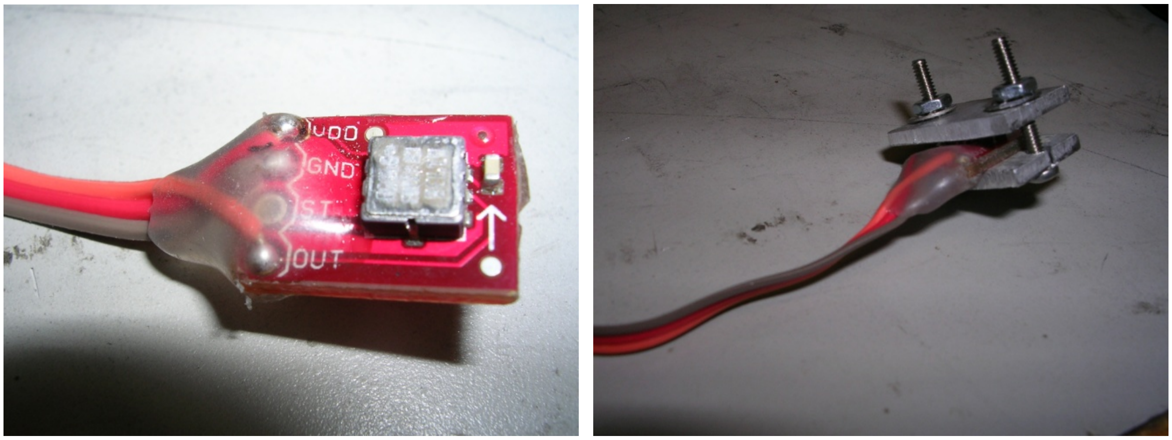

Figure 4.2: Accelerometer Breakout Board & Vertical Mount

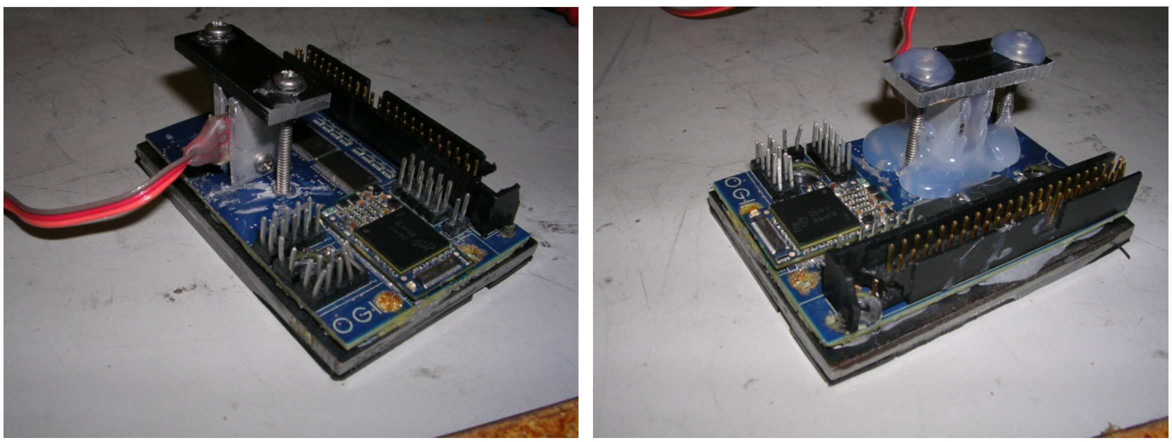

Figure 4.3: Accelerometer Mounted to Torpedo Carrier Board

4.1.4 Test Setup Description

The Torpedo constrained drop test fixture was created to simulate a worst case scenario. The Torpedo carrier board was created first, as seen in Figure 4.3. A 250 G accelerometer was wired up and secured with hot glue to keep the wires from breaking off. This accelerometer was a single-axis type in the direction of the arrow, as shown in Figure 4.2, so it had to be mounted vertically on the carrier board. This was done using two pieces of aluminum bolted together (second picture in Figure 4.2). This setup was then secured to the carrier board using another inch-long piece of aluminum (Figure 4.3) and two screws with lock nuts. Finally, the entire accelerometer setup was potted with hot glue to ensure the nuts did not loosen (second picture in Figure 4.3). This hot glue has no effect on the accelerometer; it is merely to ensure that the metal plates hold the accelerometer board securely throughout all of the testing.

The carrier board is made of 0.125" steel. This is to simulate the weight of an average portable electronic device. The Torpedo Launcher Baseboard connectors were then cut out from an existing development kit and glued to the top of the steel plate with epoxy. A 0.080" thick piece of ABS was glued to the bottom to simulate housing. After the epoxy dried, three holes were drilled through the board for guide rods. The total weight of the carrier board with an OMAP35x Torpedo SOM connected was 139.75 grams.

Once the carrier board was built, the main drop testing area had to be constructed. As seen in Figure 4.1, this was done using a 0.75" thick steel plate landing surface with two 48"-tall pieces of wood screwed onto it. It was then capped by another steel plate. Both of these plates had a three-hole pattern machined into them, corresponding to the three-hole pattern created on the carrier board. The guide rods slid through these holes on the top and secured into the holes on the landing surface. Two rods were 0.25" in diameter and the other was 0.125"; all made of stainless steel. The rods also needed to be heavily lubricated to minimize friction. The final step in completing the fixture was to slide the carrier board onto the guide rods, as in Figure 4.1, and connect the accelerometer to the power supply and oscilloscope.

4.2 Required Equipment

4.2.1 General Supplies

- Two 18" x 12" x 0.75" thick steel plates
- 2" x 3" x 0.125" thick steel plate
- 8' of 1" x 1" wood
- 8' of 0.25" stainless steel rod
- 4' of 0.125" stainless steel rod
- OMAP35x Torpedo SOMs (5x)
- Torpedo Launcher Baseboards (to be cut up)
- 8' of wire harness
- 5V power supply
- Tape measure

4.2.2 Measurement Equipment

- Oscilloscope
- Analog Devices single-axis, 250G iMEMs ADXL193 accelerometer

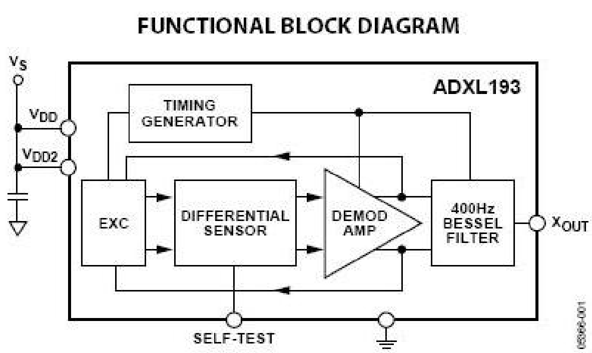

Figure 4.4: ADXL193 Accelerometer Functional Block Diagram

4.3 Test Procedure

4.3.1 Test Setup

As preparation for this test, the following steps were executed in succession:

- Powered the accelerometer with 5 volts DC.
- Set the oscilloscope to single trigger and tested to make sure it was working by tapping on the accelerometer.
- Made sure the Torpedo carrier board fell freely down the guide rails. Added more lubricant when necessary.

- Measured and marked 6" intervals on the 48" vertical wood pieces of the fixture. These were the reference points for dropping the carrier board.

4.3.2 Test Steps

The following subtests were performed and the results were recorded in the action log:

1. Inserted the OMAP35x Torpedo SOM into the connectors on the carrier board.
2. Raised and dropped the carrier board from 6" above the steel plate.
3. Checked if the OMAP35x Torpedo SOM disconnected from the carrier board and recorded the maximum G-level reached.
4. If the SOM disconnected, saved the impact waveform off the oscilloscope. Otherwise, dropped the carrier board two more times to see if the Torpedo SOM disconnected.
5. After the third drop, pushed on the OMAP35x Torpedo SOM to ensure that it was fully connected and raised the drop height.
6. Continued dropping the carrier board three times at heights of 12", 18", 24", 30", 36", 42", and 48", checking the OMAP35x Torpedo SOM after each drop and pushing it fully back into the connectors before increasing the height.
7. Once the Torpedo carrier board was dropped 3 times at 48" or the OMAP35x Torpedo SOM disconnected, the sample was complete.
8. Repeated this process for five OMAP35x Torpedo SOM samples.

4.4 Results

4.4.1 Data Results

After dropping five OMAP35x Torpedo SOMs connected to the carrier board, the results in Table 4.1 below were recorded. These were the maximum accelerometer voltages recorded off the oscilloscope during impact. They can be converted to the actual accelerations they represent, as seen in Table 4.2.

Table 4.1: Torpedo Shock Test Accelerometer Data

Drop Height (IN)	Unit 1 (V)	Unit 2 (V)	Unit 3 (V)	Unit 4 (V)	Unit 5 (V)	Average at Drop Height (V)
6"	3.82 4.1 3.82	4.46 3.82 3.86	4.02 3.98 3.98	4.06 4.14 4.22	4.06 4.26 4.34	4.06
12"	3.94 4.18 4.14	3.7 4.1 3.62	4.14 4.14 3.78	3.66 4.42 4.1	4.42 4.46 4.3	4.07
18"	4.3 3.74 4.3	4.82 4.1 3.58	4.54 4.06 4.54	4.5 4.02 4.62	4.62 4.62 4.7	4.34
24"	3.82 4.1 3.38	4.54 4.18 3.78	4.82 4.58 4.74	3.98 4.26 4.66	4.46 4.58 4.26	4.28
30"	4.62 4.1 4.74	3.94 4.1 4.26	4.38 4.02 4.46	4.1 4.9 4.78	4.7 4.38 4.82	4.42
36"	4.78 4.9 4.9	4.06 4.9 4.3	4.3 4.7 4.14	4.9 4.06 4.26	4.54 4.42 4.82	4.53

Drop Height (IN)	Unit 1 (V)	Unit 2 (V)	Unit 3 (V)	Unit 4 (V)	Unit 5 (V)	Average at Drop Height (V)
42"	4.94 4.82 4.9	4.18 4.9 4.42	4.26 4.9 4.9	4.42 4.94 4.9	4.26 4.94	4.69
48"		4.86 4.82 4.78	4.82 4.82	4.42 4.9 4.7		4.77

As can be seen from the table, Units 1, 3, and 5 all disconnected from the carrier board. This only occurred when a drop height of 42 inches or greater was reached. Units 2 and 4 remained connected throughout the entire drop test. In the far right column of Table 4.1 are the average voltages for each drop height. While it was difficult to consistently get the carrier board to hit flat every time, these averages still steadily increased with the drop height. Table 4.2 contains the values of the corresponding impact acceleration to these voltages.

Table 4.2: Torpedo Drop Test Impact Accelerations

Drop Height (IN)	Unit 1 (G)	Unit 2 (G)	Unit 3 (G)	Unit 4 (G)	Unit 5 (G)	Average at Drop Height (G)
6"	165 200 165	245 165 170	190 185 185	195 205 215	195 220 230	195
12"	180 210 205	150 200 140	205 205 160	145 240 200	240 245 225	197
18"	225 155 225	290 200 135	255 195 255	250 190 265	265 265 275	230
24"	165 200 110	255 210 160	290 260 280	185 220 270	245 260 220	222
30"	265 200 280	180 200 220	235 190 245	200 300 285	275 235 290	240
36"	285 300 300	195 300 225	225 275 205	300 195 220	255 240 290	254
42"	305 290 300	210 300 240	220 300 300	240 305 300	220 305	274
48"		295 290 285	290 290	240 300 275		283

The OMAP35x Torpedo SOM disconnected at 300, 290, and 305 G. These are relatively high impacts. Figure 4.5 below is the corresponding waveform taken from the oscilloscope when Unit 1 extracted. In this graph, the initial impact and rebound can be seen.

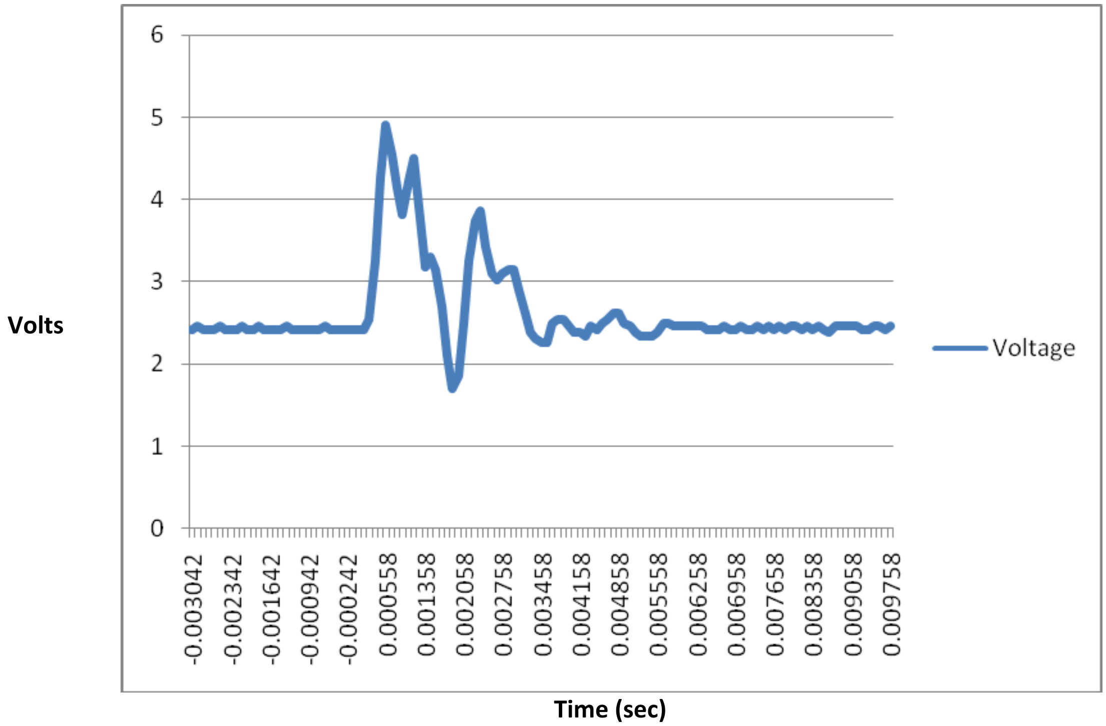

Figure 4.5: Accelerometer Voltage during Impact as Unit 1 Disconnected

4.5 Conclusions

Based on these results, a drop of 42 inches or higher can dislodge the OMAP35x Torpedo SOM. It is crucial to keep in mind that this was a worse-case scenario. The Torpedo carrier board was dropped nearly flat on top of a steel plate and impacted onto steel every drop. In reality, the carrier board would have some rotation with a lot more give in the housing.

5 Summary of Results

Having knowledge of a product's environment is crucial to its design. Does the product rest in a vehicle where it will undergo heavy vibration? Is it a handheld product that will be dropped numerous times? For the OMAP35x Torpedo SOM, this is especially important since it can be disconnected from its baseboard with 5-10 pounds of force. While this may seem low, in order to physically pull the SOM off the baseboard while it is in use, the user would have to catch a corner of the OMAP35x Torpedo SOM PCB. The likelihood of this actually occurring is low since the board is situated a mere 2.0 mm off the baseboard. If the OMAP35x Torpedo SOM will be used while experiencing vibration, it can withstand 40 G of acceleration. The SOM can stay connected at this high level because of its small mass. Finally, if the product would be dropped or impacted, the OMAP35x Torpedo SOM can withstand a worse-case impact of up to 36 inches or 300 G of acceleration. If there is any question of whether the OMAP35x Torpedo SOM will experience any conditions outside of these limits, a retention system should be used.

6 Retention System Recommendations

Some products may require the OMAP35x Torpedo SOM to be secured to the baseboard to ensure it never disconnects. Logic PD recommends that the OMAP35x Torpedo SOM be secured either by retaining it in place by the surrounding enclosure or using the Logic PD-designed clip.

NOTE: The drawings included below are also available in Logic PD's *WP 419: Torpedo SOM Mechanical Hold-Down Scenarios*.[1]

6.1 Enclosure

The most efficient method to ensure the OMAP35x Torpedo SOM remains connected is to use the surrounding housing as a support. This can be in the form of ribs, brackets, bosses, etc. Any desired feature can be built to rest gently above the top surface of the processor. The advantage of this system is that it requires no extra parts and does not alter the size of the OMAP35x Torpedo SOM's profile. The drawing below is an example enclosure securing the OMAP35x Torpedo SOM with the enclosure cover.

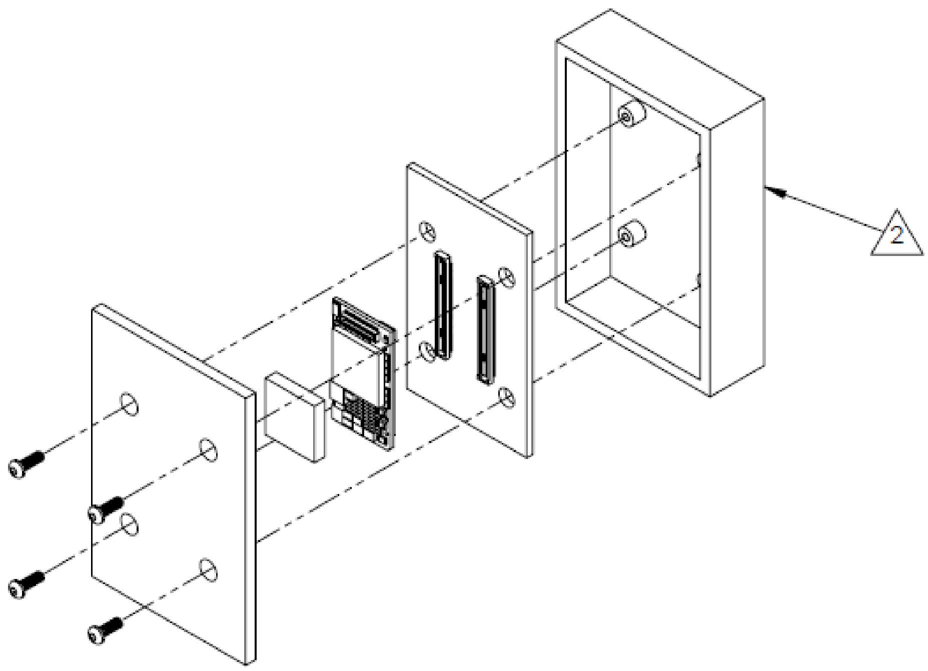

Figure 6.1: Torpedo In-Housing Retention System Assembly

6.2 Logic PD-Designed Hold-Down Clip

If space is of less concern, a Logic PD-designed Torpedo SOM Hold-Down Clip can be used. This clip was designed to have the least impact on the board's profile, while still maintaining enough strength to hold the SOM securely. It requires an extra 14 mm of width. The clip was also designed to fit into the Zoom™ OMAP35x Torpedo Development Kit, as seen is Figure 6.3, and is included in every OMAP35x Torpedo Development Kit. The standoffs, item 5 in Figure 6.3, are already connected to the development kit baseboard; item 4 is the included thermal pad.

[1] http://support.logicpd.com/downloads/1279/

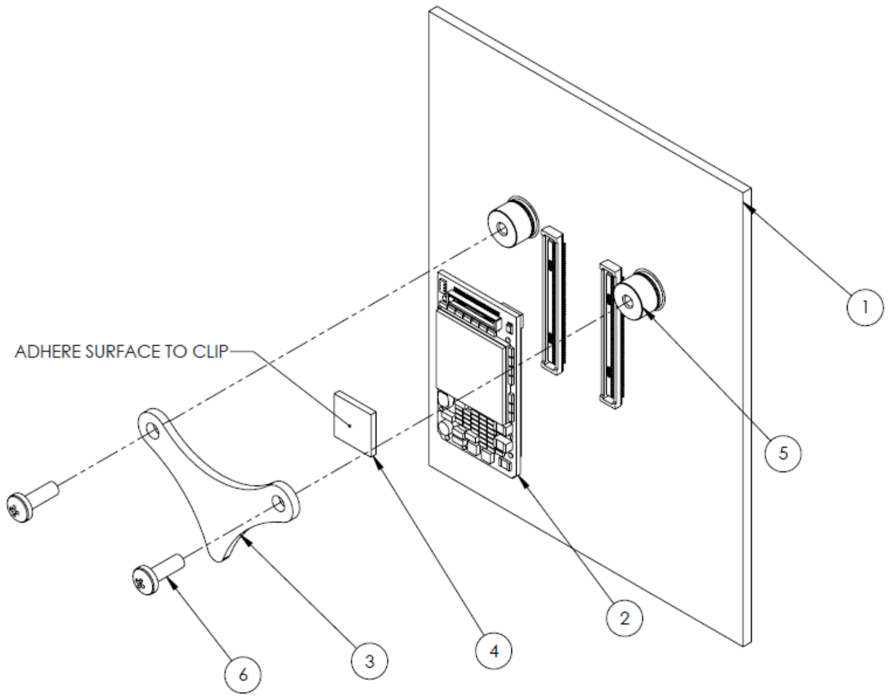

Figure 6.2: Torpedo SOM Hold-Down Clip Assembly

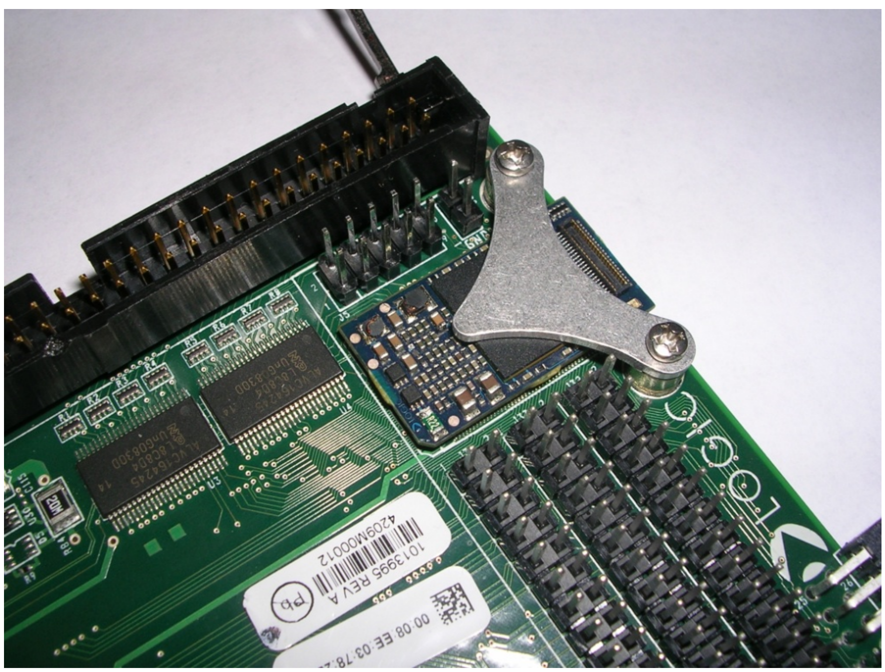

Figure 6.3: Torpedo SOM Hold-Down Clip

