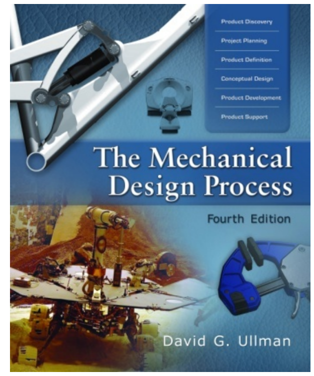
Multi-duty PC boards at Sound Devices



A Case Study for *The Mechanical Design Process*

Introduction

Sound Devices designs and manufactures equipment that records the sounds you hear in movies. The 788T High Resolution Digital Audio Recorder is a powerful eight input, twelve-track digital audio recorder designed for production sound. It records and plays back audio to and from its internal drive, CompactFlash, or external drives, making audio recording simple and fast. This unit, introduced to the market in April 2008, is half the size and weight of the competitor's products of similar capabilities. It is so compact that can easily be carried by sound professionals in an over-the-shoulder bag.

A unique feature of the 788T is that printed circuit boards (PC boards) not only serve their intended purpose for mounting and connecting electronic components but also the physical mounting and support for the controls. This dual use of the PC boards has resulted in a very efficient design from an assembly viewpoint.

Figure 1. Sound Devices 788T

This case study will focus on the design of the Light Ring Assembly, the set of controls circled in Figure 1. Specifically:

- **The Problem**: Design a Light Ring Assembly, an assembly in the 788T High Resolution Digital Audio Recorder, which is mechanically and electronically easy to assemble.
- **The Method**: The Light Ring Assembly was designed on Autodesk® Inventor® taking into account best Design for Assembly (DFA) practice.
- **Advantages/disadvantages**: Even though this is a low volume product, the application of DFA methods resulted in a light, efficient design.

The 788T

On a movie set the soundman's job is to record audio for mixing and editing later.   Using the 788T he may record up to 8 separate channels of audio.   Often the 788T is carried in a bag as shown in Figure 2 so it must be light, small and durable as it gets banged around a lot.   788Ts have been used in rainforests, on top of Mt. Everest and in every other conceivable environment.

Figure 2. Soundman with 788T in his bag

Once the 788T is connected to microphones the soundman uses the controls to set the levels for recording.   As shown in Figure 3 (from the user's manual), the channels are activated and gains are set by using the eight pop-out potentiometers (called the Input Gain Controls) on the front of the unit.

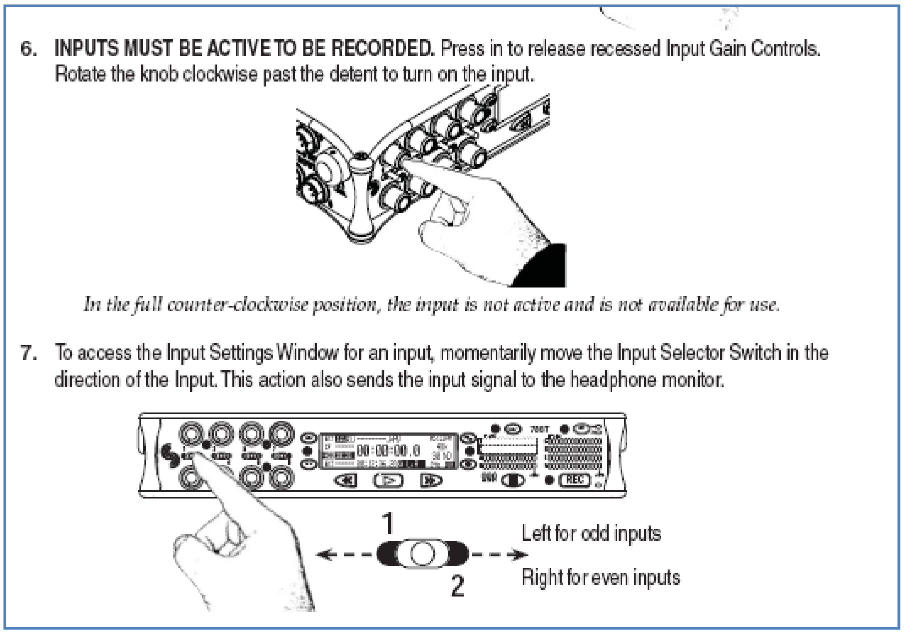


Figure 3. Details from the788T Users Manual

Using the 3-position Input Selector Switches, the soundman can listen to each of channels, one-at-a-time to hear that he has the level set so that a good signal is recorded. The Input Selector Switch is normally in the middle position but by moving it to the left or the right, the user can selected either of the two channels to send the input signal to the headphone monitor.

The Light Ring Assembly

On the 788T, the Input Gain Controls and the Input Selector Switches are part of the Light Ring Assembly.   This assembly (shown in Figures 4 and 5) was designed by Jason McDonald, a young mechanical engineer added to the Sound Devices staff in 2007.   His addition has allowed them to produce equipment that is smaller and lighter.

The Input Gain Control potentiometers for inputs 1-4 are mounted on the Upper Horizontal PC Board and those for inputs 5-8 on the Lower Horizontal PC board as can be seen in the exploded view in Figure 5. All the potentiometers are held to the board by soldered tabs and electrical connectors. Circuitry on these boards supports the potentiometers. Also on each of these boards is a connector that allows the horizontal boards to electrically plug into the Vertical PC Board.

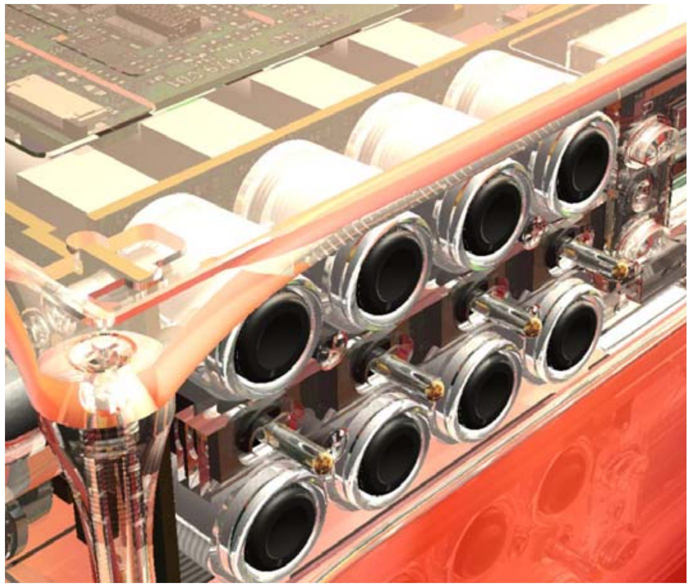


Figure 4. X-ray Isometric of the Light Ring Assembly

The vertical PC board is populated with the four 3-position Input Selector Switches, a set of LEDs for each input channel and driver chips for the LEDs. The LEDs surrounding the Input Gain Controls indicate the input activity for each channel. There are nine LEDs distributed in a circle with three red LEDs indicating that the signal is being clipped, three yellow LEDs to indicate the peak setting and three green LEDs to indicate that the channel is in use and the signal is within set limits. The LEDs feed their light into the Light Ring as will be described in a moment.

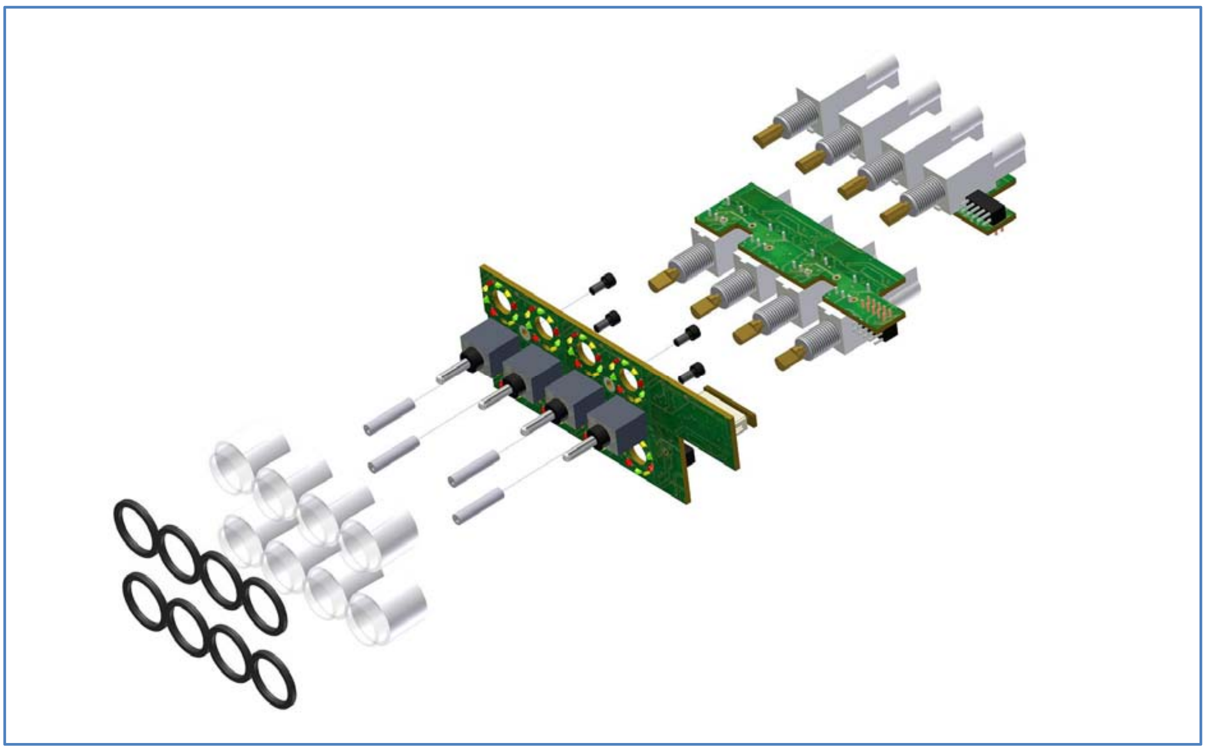


Figure 5. Light Ring Assembly Exploded View

The Horizontal Boards are mechanically fastened to the Vertical Board using the Light Rings. These are injection molded polycarbonate parts that serve multiple purposes.

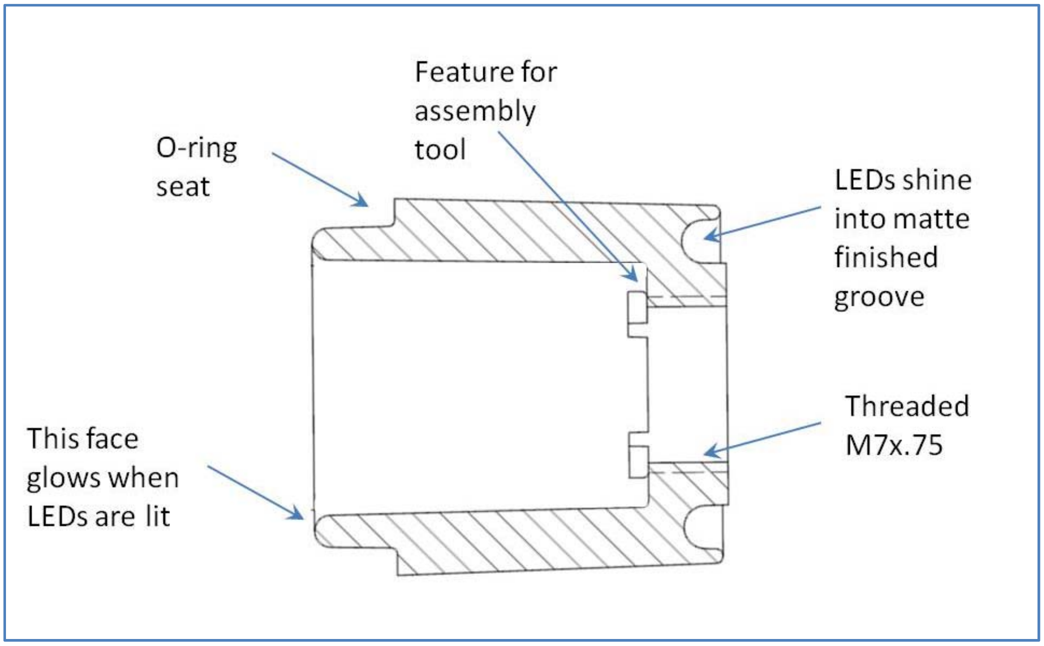


Figure 6. Light Tube Section

The section view of the Light Ring (Figure 6) shows its important features. The LEDs on the Vertical PC Board fit into the groove in the back of the Light Rings where the matte finish disperses the light in the Ring. They then transmit the LED light to the front of the unit and mix the light from the 3 same-colored LEDs to make an even circle of red, yellow or green light.

Each Light Ring threads onto a potentiometer and holds the horizontal PC boards to the vertical PC board. The Light Rings also have a grove in them to hold the O-ring (shown in Figure 5) used to keep water and dirt out of the Recorder. Finally, there are features molded into the Light Ring making the assembly easy. Jason also designed a special driver that mates to these features, shown in Figure 7.

The entire Light Ring Assembly itself is mechanically mounted to the faceplate of the Recorder with four standoffs that are screwed to the vertical PC board. These can be seen in Figure 5.

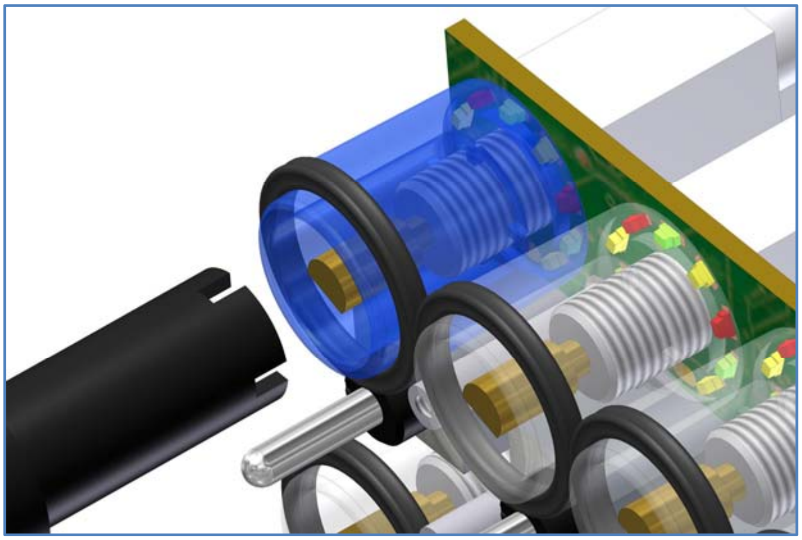


Figure 7. Light Tube with Driver

Design for Assembly (DFA) Evaluation

The cleverness of this design can be fully appreciated by performing a Design for Assembly evaluation on it. Jason did not use a formal DFA process during the design of the Assembly, so a formal evaluation is worthwhile. The evaluation used here is developed in Chapter 11 of The Mechanical Design Process. A template for this evaluation can be downloaded for free from the publisher's web site (See Sources at end of paper). The template is a Word document as shown in Figure 8. The scores shown in the diagram were entered by the author of this case study after dissecting the Light Ring Assembly. As described in The Mechanical Design Process, the scoring process is useful to guide designing. However, the value of the score itself is only useful in comparison with other, alternative configurations. To make this more interesting, parallel to describing the logic for the 788T Light Ring Assembly scores, an alternative, more traditional mounting scheme will be scored for comparison. A full description of each of these measures can be found in the reference.

Generally DFA becomes important for high volume products where the assembly costs may be a significant part of the entire cost. While the 788T is not high volume, the DFA analysis shows the quality of the design.

The evaluation for the Light Ring Assembly assumes that the electronic components are already mounted on the PC boards and so the Bill of Material (BOM) for the final assembly is:

Part	Req.
Upper horizontal PC board	1
Lower horizontal PC board	1
Vertical PC board	1
Light Rings	8
O-rings	8
Stand-offs	4
Screws for stand-offs	4
Foam rubber pads	4

These parts are shown in Figure 5, with the exception of the foam rubber pads that go on the Input Selector Switches to keep out water and dirt as do the O-rings at the Light Rings. Also, not counted or shown are the screws to attach the assembly to the faceplate.

On the form in Figure 8 the wording for each of the 13 measures are different than in the text where they are given as design guidelines. The guidelines version of the wording is used below as each of the measures is applied to the Light Ring Assembly

Overall Assembly

Guideline 1: Overall Component Count Should Be Minimized. The first measure of assembly efficiency is based on the number of components or subassemblies used. This is accomplished by comparing the minimum number of components possible to the actual number used. For the Light Ring Assembly, the total number shown in the BOM is 31 parts. In deciding the minimum number of parts necessary for the assembly, consider that the material properties of the PC boards

(DFA) Design for Assembly

Individual Assembly Evaluation for: 788T Light Ring Module | Organization Name : Sound Devices

	OVERALL ASSEMBLY	
1	Overall part count minimized	Good 4
2	Minimum use of separate fasteners	Very good 6
3	Base part with fixturing features (Locating surfaces and holes)	Very good 6
4	Repositioning required during assembly sequence	>=2 Positions 4
5	Assembly sequence efficiency	Very good 6
	PART RETRIEVAL	
6	Characteristics that complicate handling (tangling, nesting, flexibility) have been avoided	Most parts 6
7	Parts have been designer for a specific feed approach (bulk, strip, magazine)	Some parts 4
	PART HANDLING	
8	Parts with end-to-end symmetry	All parts 8
9	Parts with symmetry about the axis of insertion	All parts 8
10	Where symmetry is not possible, parts are clearly asymmetric	All parts 8
	PART MATING	
11	Straight line motions of assembly	All parts 8
12	Chamfers and features that facilitate insertion and self-alignment	Some parts 4
13	Maximum part accessibility	Most parts 6
	Note: Only for comparison of alternate designs of same assembly — **TOTAL SCORE**	78

Team member: Jason	Team member:	Prepared by: David Ullman	Date: Sept 1 2009
Team member:	Team member:	Checked by:	Approved by:

Designed by Professor David G. Ullman
Form # 21.0

Figure 8. Design For Assembly (DFA) Analysis for Light Tube Assembly

must be significantly different from the Light Rings and that the O-rings and foam pads yet different again. Further, even a single PC board must fasten to the chassis in at least 3 places. Then, the minimum number of parts is 8 Light Rings, plus 8 O-rings, plus a single foam pad, all the electronics on a single assembly and 3 snap parts to hold the PC board, totaling 21 parts. This gives an improvement potential of 32% which is considered good as indicated on the DFA work sheet, giving 4 points.

Guideline 2: Make Minimum Use of Separate Fasteners. One way to reduce the component count is to minimize the use of separate fasteners. This is advisable to ease assembly, save cost and reduce stress concentrations. Eliminating fasteners is more easily done on high-volume products, for which components can be designed to snap together, than on low-volume products. Here Jason has used the Light Rings to both channel the LED light to the front panel, to spread the light around the whole circumference, and to mechanically hold the PC boards together. The 8 Light Rings are the only mechanical connection in the assembly.

Separate stand offs are used to hold the assembly to the chassis. This is seen as an opportunity for further improvements. Based on the cleverness of the Light Ring design, the use of separate fasteners measure is very good, resulting in 6 points on the DFA worksheet.

Guideline 3: Design the Product with a Base Component for Locating Other Components. This guideline encourages the use of a single base on which all the other components are assembled. The Vertical PC Board serves as this base and all the other parts fit into through holes, or, electrically, with connectors. Thus, this measure is very good, adding 6 more points to the worksheet.

Guideline 4: Do Not Require the Base to Be Repositioned During Assembly. This measure is important if automatic assembly equipment such as robots or specially designed component placement machines are used during assembly. Here the volume is low enough that hand assembly is used, but still, this measure indicates how much the base part (the vertical PC board) needs to be manipulated during assembly. The assembly sequence begins with the vertical PC board face down where the screws that hold on the stand offs the horizontal PC boards are inserted. Then the whole assembly must be rotated 180deg to insert and screw in the Light Rings and insert the O-rings and foam rubber.

Using the scale on the DFA worksheet, the two positions add 4 more points.

Guideline 5: Make the Assembly Sequence Efficient. If there are N components to be assembled, there are potentially N ! (N factorial) different possible sequences to assemble them. For this assembly, the sequence described in the repositioning analysis seems very good, for 6 points.

Evaluation of Component Retrieval

The measures for retrieving components range from “all parts” to “no parts” on the DFA worksheet. If all components achieve the guideline, the quality of the design is high as far as component retrieval is concerned. Those components that do not achieve the guidelines should be reconsidered.

Guideline 6: Avoid Component Characteristics That Complicate Retrieval. Three component characteristics make retrieval difficult: tangling, nesting, and flexibility. Only the wire lead off the back of the Vertical PC Board fits this description and so "most parts" is indicated on the DFA Worksheet, giving 6 points.

Guideline 7: Design Components for a Specific Type of Retrieval, Handling, and Mating. The 788T is manually assembled and so parts should be designed with this type of assembly in mind. Although there are no special features on the parts to accommodate human hands, the parts are relatively easy to handle and so a neutral score of "some parts" is given, 4 points.

Evaluation of Component Handling

The next three design-for-assembly guidelines are all oriented toward the handling of individual components. They will be treated together.

Guideline 8: Design All Components for End-to-End Symmetry.
Guideline 9: Design All Components for Symmetry About Their Axes of Insertion.
Guideline 10: Design Components That Are Not Symmetric About Their Axes of Insertion to Be Clearly Asymmetric.
The end-to-end symmetric parts are the stand-offs, O-rings, and foam rubber pads. There is no end-to-end differentiation for these parts. The bolts that fasten on the stand-offs are axis-symmetric and they are symmetric about their axis of insertion... All other parts are asymmetric and can only go together one way. Thus, all three measures are as good as can be and so they are given an "all parts" score of 8 points.

Evaluation of Component Mating

Finally, the quality of component mating should be evaluated.

Guideline 11: Design Components to Mate Through Straight-Line Assembly All from the Same Direction. This guideline, intended to minimize the motions of assembly, has two aspects: the components should mate through straight line motion, and this motion should always be in the same direction. For the Light Ring Assembly "all parts" meets this, giving 8 points.

Guideline 12: Make Use of Chamfers, Leads, and Compliance to Facilitate Insertion and Alignment. To make the actual insertion or mating of a component as easy as possible, each component should guide itself into place. The potentiometer projections guide the horizontal boards into the vertical board resulting in a "some parts" score, leading to 4 points.

Guideline 13: Maximize Component Accessibility. This guideline is oriented toward sufficient accessibility to allow for grasping and absence of needing to insert parts in an awkward spot. Most parts in the assembly have good accessibility, for 6 more points.

The total score for this assembly is 78 out of a possible 100. This is very good for a product that was designed for low volume. But, as said at the beginning, this number has meaning only when compared to another potential assembly.

Summary

The 788T has been a very successful product for Sound Devices. The quality of the mechanical design has been explored by evaluating one assembly using Design for Assembly (DFA) metrics. Although the designer did not use this exact method in his design effort, it is clear that he knew the DFA guidelines and used them well.

Sources

Sound Devices
DFA Template

Author

This case study was written by David G. Ullman, Emeritus Professor of Mechanical Design from Oregon State University and author of The Mechanical Engineering Process, 4th edition, McGraw Hill. He has been a designer of transportation and medical systems and hold five patents. More details on David can be found at www.davidullman.com. Professor Ullman was assisted by Jason McDonald of Sound Devices LLC. of Reedsburg, Wisconsin.

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