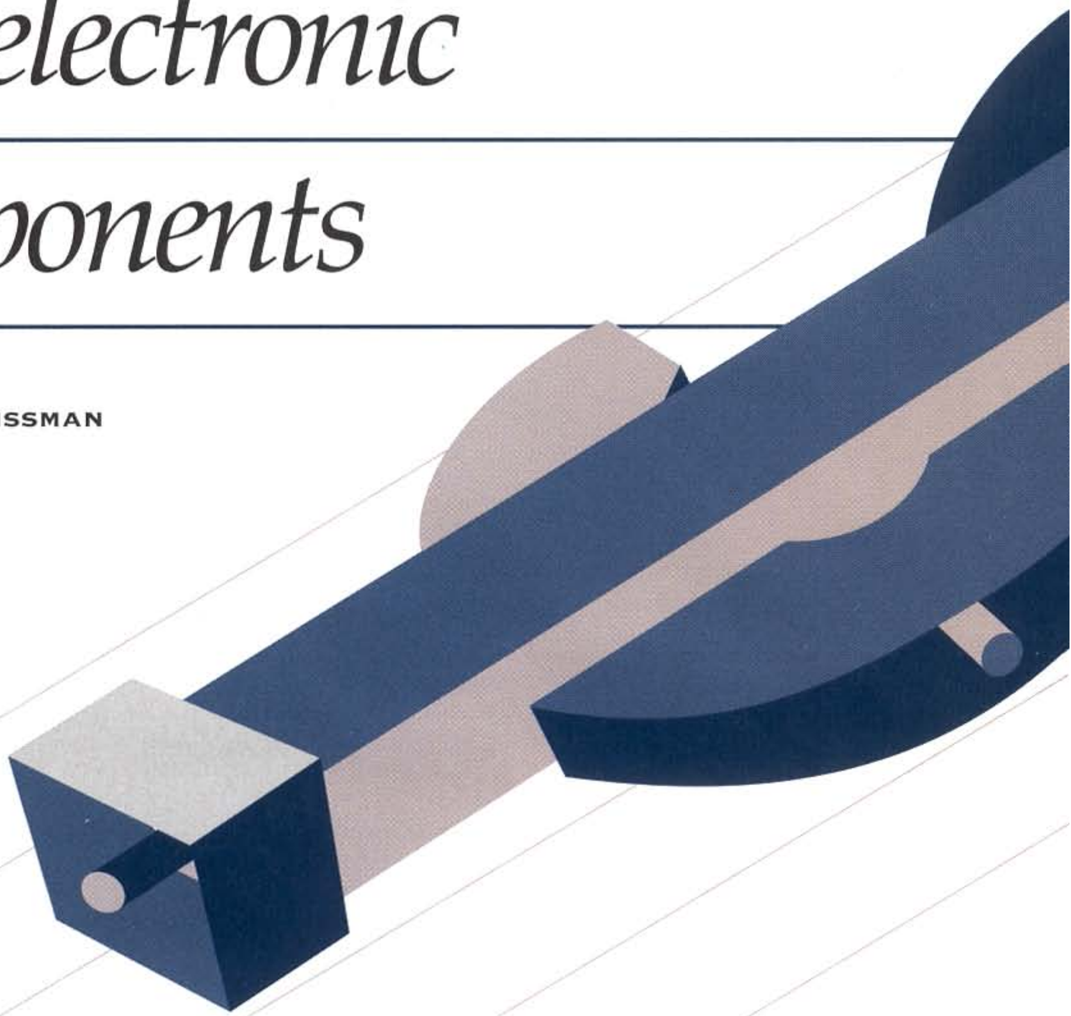
Manufacturing Low Cost Optoelectronic Components

By Robert H. Weissman



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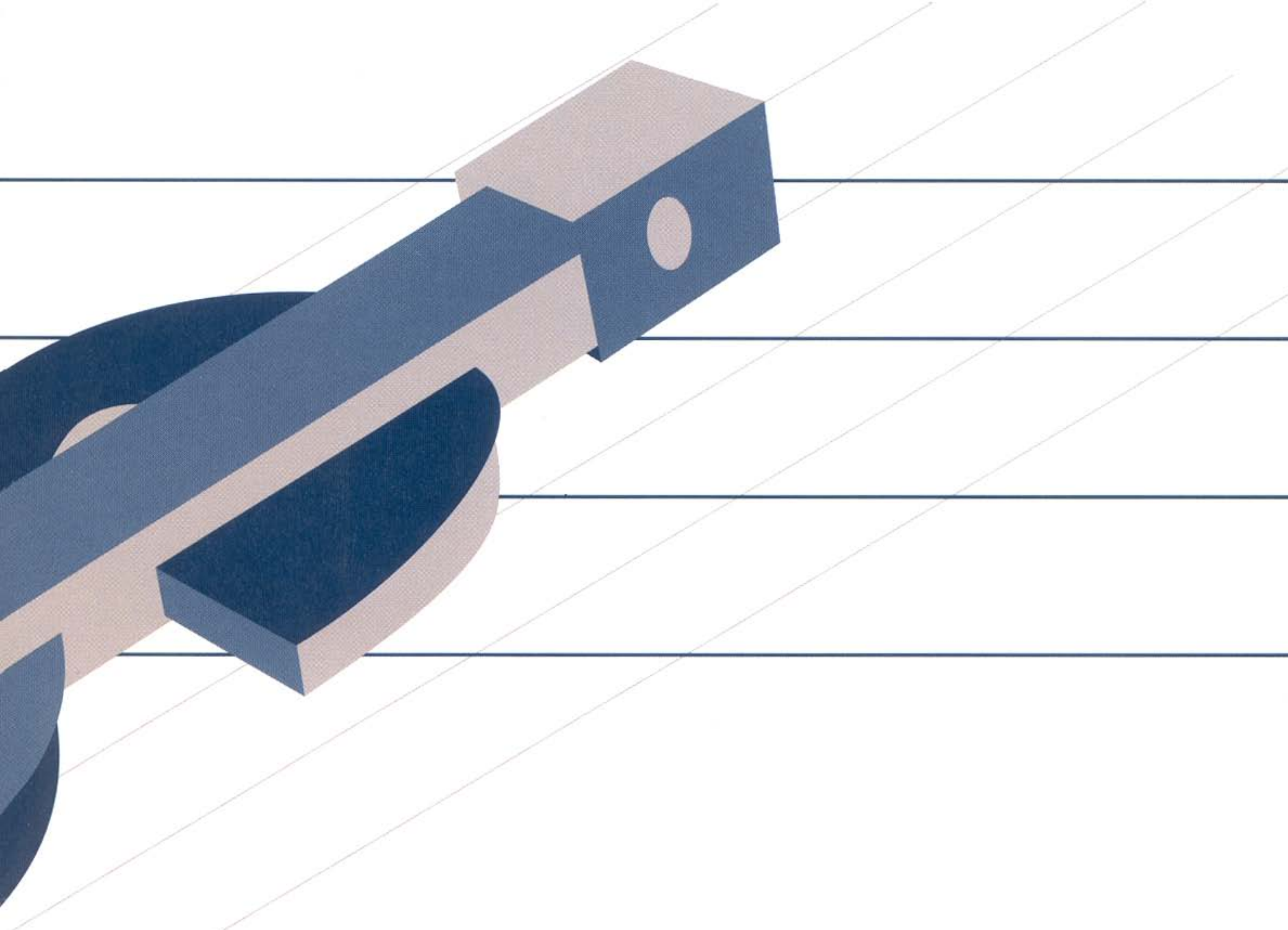

Why do some products sell well while others with considerable technical merit languish? For an optoelectronic product to be successful in the marketplace, several important elements must be simultaneously achieved. First, the performance of the product must meet customer needs. Second, the product should have excellent quality and reliability. Finally, the price must be sufficiently low that customers are willing to buy the product.

Selling price is determined to a major extent by the product's cost—the dollars it takes to manufacture each unit of product. This article discusses how manufacturing costs are calculated and how the issues of volume, yields, complexity, process robustness, and packaging impact cost. It is written for those who have little or no knowledge about manufacturing costs and presents easy to remember "rules of thumb" that provide considerable insight into what one must consider to achieve low production cost.

Researchers in new, emerging technologies should find the rules of thumb particularly valuable as they struggle with the challenge of both pushing the state-of-the-art and making a commercially valuable product. Such challenges are present in many research fields today, such as integrated photonic devices, smart pixel displays, and polymer optoelectronics.

Research and development engineers often feel that production cost is not their concern. They erroneously believe that low cost is the responsibility of the manufacturing department, overlooking the fact that a poorly designed product can never be made cheaply. Similarly, a product that uses difficult to control processes or all new processes is likely to be very expensive, as are products that are always made in very small quantities or use custom, non-standard piece parts or expensive packaging. To generalize, R&D is responsible for the following factors that critically impact product cost: (1) design simplicity, (2) complexity, robustness, and commonality of fabrication processes and piece parts, and (3) scalability to high volume.

Calculating Production Costs

Let's consider in greater detail the cost of a product. Three things are needed to produce any product: (1) raw materials (called direct material—MTL), (2) people to make the product (called direct labor), and (3) a lot of other "stuff" (called overhead). Production cost is the sum of the three; the goal of low cost requires the sum to be minimized.

For example, to make silicon photodetectors the raw materials needed are silicon, package piece parts, etc. People are needed to process the silicon into photodiodes and to assemble and test the product. Overhead items might include chemicals, tools, assembly fixtures, production space, supervision, and depreciation.

One additional concept is needed to understand how manufacturing cost is calculated. This is called cumulative process yield. Consider the simple three-step process shown in Figure 1. The arrow lines show unit flow through the three operations. For each step, input occurs at the top and output is at the bottom. Material lost at a step is shown by arrow lines exiting the step to the right. In the example shown, five units flow into Step 1. One unit is lost in Step 1, leaving four units exiting the step. Step yield is the number of "good" units exiting the step divided by total number of units entering the step. Step 1 yield = 4/5 = 0.8. Of the four units entering Step 2, one unit is lost at Step 2. Therefore, Step 2 yield = 3/4 = 0.75. As seen in Figure 1, no units are lost in Step 3, so Step 3 yield = 3/3 = 1.0.

Calculating Cumulative Yield

Cumulative yield of any step is defined as the product of the yield at that step times the step yields of any steps that follow. In Figure 1, the cumulative yield of Step 1 is 0.6 ($0.8 \times 0.75 \times 1.0$), the cumulative yield of Step 2 is 0.75 (0.75×1.0), and the cumulative yield of Step 3 is 1.0.

It is easy to show that to produce an output of "N good" units at any step, the number of units required to enter the step = N divided by the cumulative yield for the step. For the three-step process shown in Figure 1, to produce three "good" units

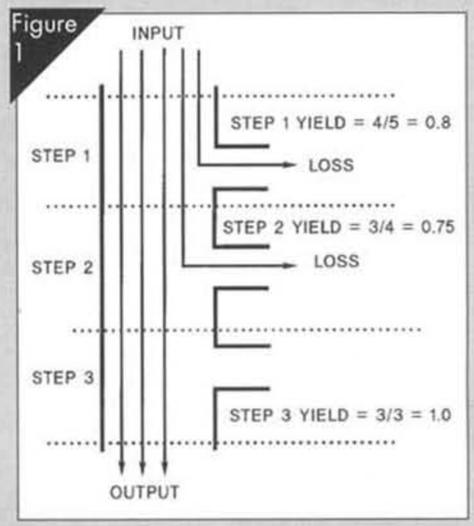

Table 1a

STEP #	MTL COST ADDED ($/UNIT)	CUM YIELD	YIELDED MTL COST ($/UNIT)
1	1.20	0.6	1.20/0.6 = 2.00
2	0.75	0.75	0.75/0.75 = 1.00
3	0.50	1.0	0.50/1.0 = 0.50
TOTAL	2.45		3.50

Table 1b

STEP #	CUM YIELD	YIELDED MATERIAL COST ($/UNIT)	YIELDED LABOR COST ($/UNIT)	YIELDED OVERHEAD COST ($/UNIT)	YIELDED TOTAL COST ($/UNIT)
1	0.6	2.00	0.10	4.00	6.10
2	0.75	1.00	0.40	2.00	3.40
3	1.0	0.50	1.00	1.00	2.50
TOTAL					12.00

Figure 1
Simple three-step process showing unit flow through each step. Yields for each step are shown. Step 1 cumulative yield = 0.6, Step 2 = 0.75, Step 3 = 1.0.

Table 1a & 1b
Material cost (*a*) and total cost (*b*) of a "good" unit.