Chapter 3

TEST ECONOMICS AND PRODUCT QUALITY

> "*. . . Economics is the study of how men choose to use scarce or limited productive resources (land, labor, capital goods such as machinery, and technical knowledge) to produce various commodities (such as wheat, overcoats, roads, concerts, and yachts) and to distribute them to various members of society for their consumption . . .*"
>
> — Paul Samuelson [560].

Engineering economics is the study of how engineers choose to optimize their designs and construction methods to produce objects and systems that will optimize their efficiency and hence the satisfaction of their clients. We discuss engineering economics concepts, such as the analysis of production and operational costs, and benefit versus cost analysis. These concepts, when applied to electronic test, lead to economic arguments that justify *design for testability* (DFT) [23].

Engineers are concerned with optimizing the *technological* efficiency. For example, in designing a heat engine, the prime consideration is to have as much heat energy converted into mechanical work as is possible. An economist, on the other hand, prefers to minimize the cost of obtaining mechanical work for the consumer. Apart from the technological (or energy conversion) efficiency, other factors such as fixed and variable costs of material, equipment, labor, insurance, etc. are important.

Lately, test economics has received noticeable attention. The relationship between testing cost and product quality is complex. For large electronic systems, testing accounts for 30% or more of the total cost. Still, it has been hard to justify the cost of DFT at the component level. We will examine the impact of DFT on the overall system cost rather than considering the component cost alone.

Study and practice of economic principles are as important for engineers as the laws of physics. We may find ourselves pursuing local goals such as *profitability, time to market,* and *beating the competition,* but the real goals are usefulness to society and preservation of the environment. Today, economics is a well developed science, divided into two main streams. *Microeconomics* is the study of economic laws at a small scale as affecting a company. *Macroeconomics* deals with the wealth of society at the national or international scale. We briefly introduce microeconomics, including costs, production, and benefit-cost analysis, and study the case for *built-in self-test* (BIST) in electronic products.

VLSI yield, product quality measured as defect level, and fault coverage are important concepts related to electronic production and testing. These are discussed in the later part of this chapter.

3.1 Test Economics

Testing is responsible for the quality of VLSI devices. Several tradeoffs are often necessary to obtain the required quality level at minimal cost. Costs include the cost of *automatic test equipment* (ATE) (initial and running costs), the cost of test development (CAD tools, test vector generation, test programming), and the cost of DFT [204, 522]. In the future, DFT will dominate test economics equations. The scan design technique can significantly reduce the cost of test generation and the BIST method can lower the complexity and cost of ATE. DFT techniques should, therefore, be included in the device specification and the test plan.

3.1.1 Defining Costs

Cost is a measurable quantity that plays a key role in economics. For example, we compare costs and benefits to select between alternatives, or minimize cost to optimize a design. As we define below, there are several types of costs.

Fixed Costs (FC.) These are the costs of things that are necessary but do not change with use. For example, if we wish to produce computers, we require a factory building and machinery which contribute to fixed costs. These costs do not change with the number of computers that are built, whether we build one or one thousand computers. Although fixed costs remain unchanged, the fixed costs per computer will reduce as the production is increased.

Variable Costs (VC.) These costs increase with the production output. The variable costs of producing one thousand computers will be one thousand times greater than the variable costs of producing one computer. Variable costs generally consist of labor, energy, and raw materials.

Total Costs (TC.) Total costs are the sum of the fixed and variable costs, and increase with production output.

Average Costs (AC.) These are obtained by dividing the total costs by the number of units produced.

As an illustration, consider the cost analysis of car transportation for an individual. We take the purchase price of the car, say \$25,000, as the *fixed cost.* We estimate