IC KNOWLEDGE LLC

Applications Note

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Cost, Price and Volume

There is a complex and often misunderstood relationship between cost and price, and the effects of volume on both. In this application note I will explain the various terms and interrelationships.

Definitions of Cost, Price and Volume

Before discussing the interrelations between cost, price, and volume it is useful to define the terms to insure consistent usage:

1. Cost – cost refers to the manufacturing cost of an item, also known as Cost of Goods Sold (COGS) in accounting terminology. COGS is the material, labor, and overhead costs to manufacture an item. In all the IC Knowledge cost and price models, cost is COGS. COGS do not include Selling, General and Administrative Costs (SG&A) or Research and Development (R&D) costs, these are 'below the line" costs that are absorbed into gross margin.
2. Price – the amount a third party pays to buy an item. Surprisingly cost and price can be disconnected from each other with items selling at prices both above and below cost.
3. Gross Margin – the difference between the price and the cost, gross margin is price minus cost or more broadly for a company:

   Gross Margin = Revenue (sales) – COGS

   Gross Margin is typically positive but can and is sometimes negative. In fact some companies, for example SMIC have had negative gross margins for years. Gross Margin is broadly made up of SG&A, R&D and Operating Income (profit before taxes and interest). Gross margin is applied to cost when an item is transferred to a third party.
4. Volume – the number of units purchased in a specific time period, may also be dollars purchased in a specific time period.

Semiconductor Production

The production of semiconductors can broadly be described by the following steps (see also figure 1):

1. Starting wafer – a purchased thin disc of semiconductor material, typically silicon and typically 150mm, 200mm or 300mm in diameter that is started into the wafer fabrication process.
2. Wafer fabrication – a starting wafer (purchased) is run through a series of process steps in a wafer fabrication facility to produce a finished wafer.
3. Wafer sort – a wafer will have some number of semiconductor die arrayed on the surface. Wafer sort tests each die and either marks defective die with an ink dot or in a digital map.
4. Packaging – in the packaging process wafers are sawn up into individual die and the die are assembled into protective packages.

5. Class test – the packaged die are tested to insure they meet all of the specifications.

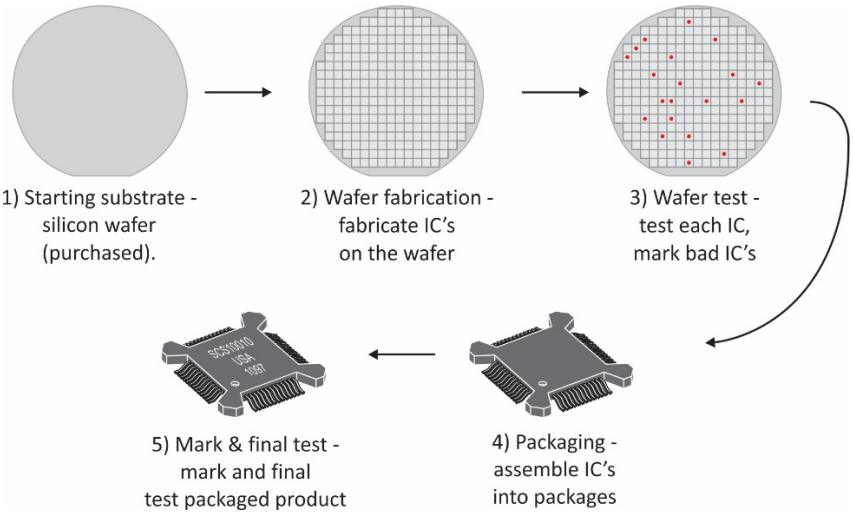

Figure 1. The Semiconductor Manufacturing Process.

There are two main types of company models in the semiconductor industry:

1. Integrated Device Manufacturer (IDM) – a company that designs and manufactures semiconductors.
2. Fabless – a company that designs semiconductors and utilizes third parties for manufacturing.

There are a variety of variations to these two types, for example some IDMs manufacture some products and outsource manufacturing of others, even IDMs that fab their own parts may outsource assembly and test.

Manufacturing Definitions

To ensure consistent usage, it is useful to define some manufacturing terms:

1. Wafer Fabrication Facility – a Wafer Fabrication Facility is a facility where a starting wafer is put through a series of steps to create a finished wafer. Wafer Fabrication Facilities are also referred to as Wafer Fabs or just Fabs.
2. Foundry – a Wafer Fab that fabricates wafers for other companies. A Fabless company outsources their wafer fabrication to a foundry.
3. Outsourced Assembly and Test (OSAT) – an OSAT is a company that performs assembly into packages and/or testing for other companies. Fabless companies and even many IDMs utilize OSATs for assembly and test.
4. Utilization - the percentage of capacity that a manufacturing operation is running at.

Finished Wafer Costs

Finished wafers are fabricated in wafer fabs. The cost to produce a wafer through a wafer fab depends on the technology generation, the process steps used to fabricate the finished wafer, the country the

fab is located in, the capacity of the fab, the age and depreciation status of the equipment and the fab utilization.

Wafer fabs are expensive to build and have high fixed costs meaning that wafer cost varies with volume, but most customers don't buy enough wafers to materially effect the cost of making a wafer. Foundries typically assume a 90% utilization when calculating their wafer costs and then apply varying margins to customer sales depending on the customer size.

In our Discrete and Power Products Cost and Price Model and IC Cost and Price Model the 'Main Selection' sheets have a table that fills in with margin and selling price for foundry wafers when a foundry process is selected. Our Strategic Cost and Price Model has a similar table on the 'Cost Sum' sheet. Our MEMS Cost and Price Model has foundry margin for both MEMS Wafers and IC Wafers. Our models all use 90% utilization for cost calculations (unless the user overrides the value) and then applies a margin for foundry wafers driven by the foundry and the selected volume.

Test and Assembly Cost

Test and assembly have also become highly automated with high fixed cost. Test and assembly facilities are typically very large, at least at the OSATs and as with wafer fabs a single customers volume won't typically affect cost much. We calculate costs for these operations assuming typical utilization rates and once again offer margin adders for OSATs based on the company and volume.

Gross Margins

As previously mentioned, gross margins are applied when an item is transferred to a third party. When gross margins are applied therefore depends on the manufacturing model being employed.

- Pure IDM – wafer fabrication, wafer sort, packaging, and class test are all performed internally, a gross margin is applied when the finished product is sold.
- Fabless – wafer fabrication is done at a foundry and the foundry charges a foundry margin when they sell the wafers to the fabless company. The fabless company will also typically use an OSAT for test and packing and pay a margin when the products are transferred back from the OSAT. Finally, a margin will be applied when the final product is sold.

There are also hybrid models, some fabless companies do some or all of their own testing or an IDM might outsource test or packaging or both.

In our models foundry margins are applied when a foundry is used, assembly margins are applied for outsourced assembly and finally a product gross margin may be applied at the end. Our Discrete and Power Products Cost and Price Model and IC Cost and Price Model both have lookup tables for average gross margin by company for finished products.