Lecture 1 & 2

Embedded System Design

Embedded System: A computer system contained by a larger electronic or mechanical device, repeating a particular function.

Design: The manner of converting a concept into an implementation through a systematic procedure.

Common embedded systems characteristics:

1. **Single functioned:** Executes a specific program repeatedly.
2. **Tightly constrained:** Tight constrains on design metrics.
3. **Reactive & Real time:**
   - Reactive: Continually reacts to changes in the system's environment.
   - Real time: Compute certain results in real time without delays.

The design challenge:

The designer of an embedded system should always construct an implementation that optimizes several design metrics. This is not an easy task because improving some metrics usually worsen others.

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Design Metric: Any measurable feature in a system's implementation.

Common Design Metrics:

1. NRE cost (Non Recurring Engineering cost):
   The one time monetary cost of designing the system.
2. Unit cost: The monetary cost of manufacturing a single copy of the system.
3. Size: a. Software: measured in Bytes.
   b. Hardware: measured in gates or transistors.
4. Performance: The execution time of the system.
5. Power: The amount of power consumed by the system, which has an impact on:
   a. Lifetime of the battery.
   b. Cooling requirements of the IC.
6. Flexibility: The ability to change the functionality of the system without incurring heavy NRE cost.
7. Maintainability: The ability to modify the system after its initial release.
8. Time-to-Prototype: The time needed to build a working version of the system.
9. Time-to-Market: The time needed to develop a system to the point where it can be released & sold to customers.
10. Correctness: To be sure the system's functionality is correct.
11. Safety: The probability of which the system won't cause harm.

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Time to Market:

Introducing an embedded system to the market place early will affect the system's profitability dramatically. Delays are costly since market windows for products are becoming quite short. For example, while a device with a certain processor is delayed, a competitor releases a device with a state-of-art processor and better capabilities. People will tend to buy the released device causing a big loss in profit for the delayed one.

Revenue & Profit:

Before digging deep into calculations, let's look at the definitions of revenue and profit. Although both words have something to do with earnings, they still have different meanings.

Revenue: The total monetary amount brought in from selling goods & services.

Profit: The revenue minus the expenses/cost.

Example:

If you bought a 5KD pepperoni pizza and sold each one of its 8 slices (# of units) for 1 KD (per product cost), you will end up with a revenue of 8 KD, however, your profit is only 3 KD which is the revenue minus the price for which you bought the pizza (expenses).

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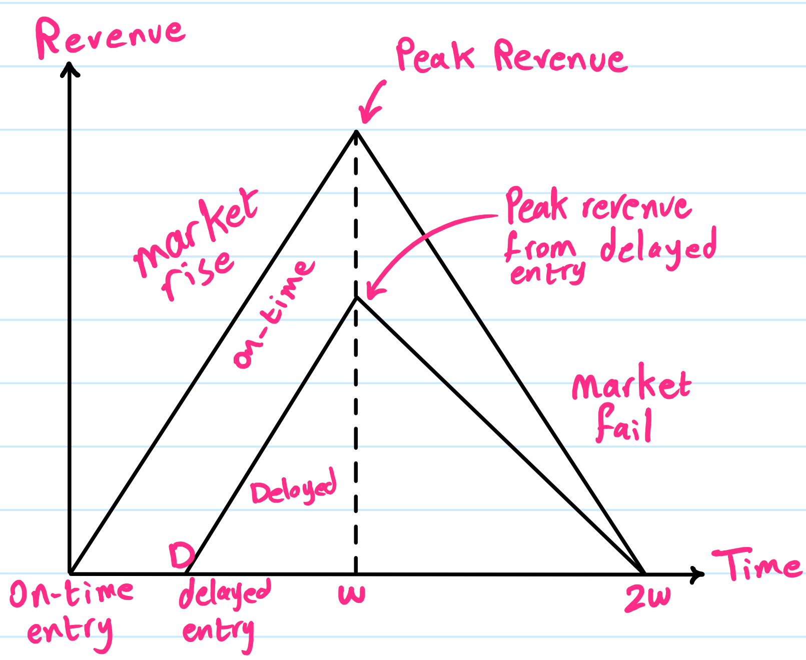
Loss of revenue:

There are several models to calculate the loss of revenue for a delayed product, some of which are simple and some are more complex yet more accurate. However, they all agree on one thing, and that is: delays in time to market are costly, the loss could even reach up to millions of dollars!

The figure below shows a simplified revenue model to calculate the loss that occurs due to a delayed entry. The revenue for an on-time entry is the area of the big triangle while the revenue for a delayed entry is the area of the small one.



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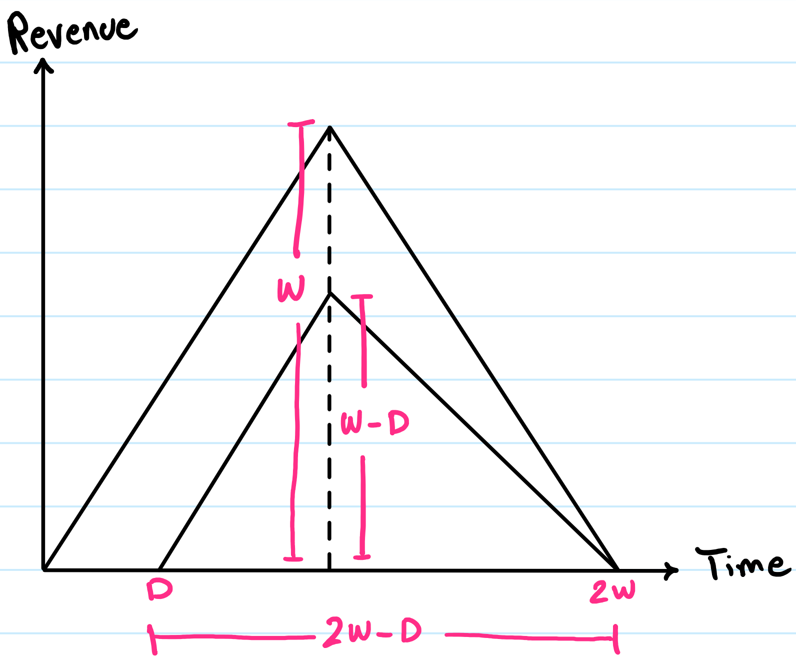

Area of triangle = $\frac{1}{2} \times$ base $\times$ height

school stuff!

Therefor, by looking at the two triangles above :

$$\text{Revenue}_{\text{on time}} = \frac{1}{2} \times 2W \times W = W^2$$

$$\text{Revenue}_{\text{delayed}} = \frac{1}{2} \times (2W-D) \times (W-D)$$

$$= \frac{1}{2} \times (2W^2 - 3WD + D^2)$$

Finally, the % loss in revenue is:

$$\frac{\text{Revenue}_{\text{on time}} - \text{Revenue}_{\text{delayed}}}{\text{Revenue}_{\text{on time}}} \times 100\%$$

$$= \frac{W^2 - \frac{1}{2}(2W^2 - 3WD + D^2)}{W^2} \times 100\% = \left(\frac{3D}{2W} - \frac{D^2}{2W^2} \right) \times 100\%$$

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Example:

Let's say we have a product with a life of 52 weeks which was delayed for 8 weeks, calculate the percentage loss in revenue.

Product life = 52 weeks → $2W = 52$

$\therefore W = 52/2 = 26$ weeks

The delay = 8 weeks → $D = 8$

Now simply substitute in the equations:

$$\% \text{ revenue loss} = \left(\frac{3D}{2W} - \frac{D^2}{2W^2}\right) \times 100\%$$

$$= \left(\frac{3(8)}{2(26)} - \frac{(8)^2}{2(26)^2}\right) \times 100\%$$

$$= \left(\frac{24}{52} - \frac{64}{1352}\right) \times 100\%$$

$$= 41.42\%$$

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Cost, Revenue, Profit & NRE cost

Previously we stated the difference between profit and revenue. Mathematically, we can derive equations to calculate the total cost, total revenue and the profit.

Basically :

$$\text{Profit} = \underbrace{TR}_{\text{Total Revenue}} - \underbrace{TC}_{\text{Total Cost}}$$

TC is the combined cost of developing the system (NRE cost) and manufacturing cost of the units.

TR is what we gain by selling all units for a certain selling price.

Therefor,

We hate this!!

$$TC = \text{NRE cost} + (\#\text{units} * \text{Unit cost})$$

$$TR = \#\text{units} * \text{selling price}$$

We love those!!

$$\therefore \text{Profit} = (\#\text{units} * \text{selling price}) - [\text{NRE cost} + (\#\text{units} * \text{unit cost})]$$

One important thing to consider here is the BEP (Break Even Point) where $TR = TC$ or in other words, $\text{Profit} = 0$

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Exercise:

Our team designed a Burger Machine for which the overall design cost was 500,000 KD (including salaries, buying parts, etc..), then our agents flew to China to manufacture 100 machines. The agents & manufacturers agreed to a manufacturing price of 2000KD per machine.

1. What is the selling price in order to reach the BEP?

2. What is the selling price in order to gain a profit of 1,000,000 KD?

3. If we still wanted a profit of 1,000,000 KD but increased the number of manufactured machines to 5000 units, what is the new selling price?

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