FabTime Cycle Time Management Newsletter

Volume 2, No. 7 August 2001

Information

Mission: To discuss issues relating to proactive wafer fab cycle time management.

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Welcome

Welcome to Volume 2, Number 7 of the FabTime cycle time management newsletter. The newsletter distribution list recently passed 500 subscribers, something of a personal milestone for me. One change that we made recently that has helped the newsletter to grow was to add a sign-up form to FabTime's website (at http://www.fabtime.com/newsletter.htm). There are abstracts to all of the past issues there, too.

This month we have several responses to prior newsletter topics - including requests for more detail on ordering SEMI standards and on the INFORMs document-on-demand service that we mentioned last month. We also have two different inquiries on cycle time benchmarking. Our announcements include a press release about an agreement that FabTime has reached with Managed Outsourcing, Inc., to use their jTask performance-based training software for all of our training classes. You can see more information below, and on our website.

Our new topic for the month is a description of a new Excel-based tool that we've made available from our website. It's a characteristic curve generator for single tools with failures. You can enter parameters for process time, mean time between failures, downtime percentage, and system coefficients of variation for up to three scenarios. The calculator then displays characteristic curves for the scenarios, allowing you to get a quick visual impression of the impact of both downtime and variability attributes. We hope that you'll find it useful.

Thanks for reading! -- Jennifer

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Responses to Previous Newsletter Topics

How to Order the SEMI E79-2000 Document

Homer Wu of Chartered Semiconductor asked: "May I know where can I find the "SEMI E79-0200" document that mentioned in your OEE article? Is it a Sematech doc?"

FabTime response:

This document is only available from SEMI. You can purchase it from their website (via credit card). This is the information on the website:

Downloadable Standards are $50 each (Members and Non-members) unless you have a prepaid Web Download Package. You may view the abstracts of the Standards without becoming a registered user. To download Standards, you must be a registered user and have Adobe Acrobat Reader 4.0 (downloadable FREE from the following web site: www.adobe.com). Use the registration form to become a registered user.

You can find E79 at www.semi.org/PUBS/SEMIPUBS.NSF/174288043ec0808d882565f6000b285b/a34b8f0e38c9e987882567450070d447!OpenDocument

For something easier than copying this link, go to www.semi.org, click on the Downloadable Standards link in the left-hand pane, then click on Equipment Automation/Hardware. Go to the bottom of the screen and click Next to get to the second page in this category, and look for E79 (they are in numeric order).

Abstracts to INFORMS Papers

Bob Kotcher asked: "Does INFORMS have a website where we can peruse abstracts, or at least titles?"

FabTime response:

An excellent question about INFORMS. You can view abstracts at www.informs.org/Pubs/. Click on PubsOnline to view abstracts and tables of contents. You'll be logged in via a guest account, and can download abstracts in PDF. There is no form for ordering the articles, however, which is why I included all of the detailed ordering information in the last newsletter. My guess is that they plan to include a form for ordering articles directly from the website, but this does not appear to be available yet.

Fab Cycle Time Benchmark Data

Another subscriber wrote: "I found your newsletter very interesting and informative. I do have a question: For a foundry, what is considered a competitive cycletime or worldclass standard in terms of X-Theoretical Cycletime (less than 3 X Theoretical for example?). Where can I obtain some benchmark data?"

FabTime response:

Thank you for your feedback regarding the newsletter. We're glad that you are finding it interesting. We have some information about cycle time benchmark data. The latest Berkeley Competitive Semiconductor Manufacturing study said that world-class cycle time should be 1.4 days/mask layer for both logic and memory fabs. This was for data at full volume for an 8" fab in 1999. In the Berkeley study, up to 3 days per mask layer was not uncommon. Cycle time was worse in the mid-90's, but came down in 97 and 98. You can find more information about the Berkeley CSM results at http://www.me.berkeley.edu/esrc/csm/. There are various reports that can be purchased from the website.

There is also some information in the SEMATECH International Technology Roadmap (see http://public.itrs.net/ for information about the Roadmap). Cycle time related information is in the Factory Integration section of the roadmap. The existing roadmap sets world-class ct/mask layer for non-hot lots = 1.75 days (1.2 days for hot lots), for high-volume, low-mix fab. The benchmark is 1.8 days per mask layer (and .9 days for hot lots) for high vol/high mix. For 300 mm fabs in 2001 the benchmark is estimated at 1.5 days/1.0 day (non-hot/hot) for low-mix and 1.6 days/.85 days for high mix. These numbers assume hot lots are less than 3% of lots, with 5 to 10 wafers per hot lot, for the low mix fab, and hot lots less than 10% for the high-mix fab. These numbers seem to represent things that are achievable by market leaders, not necessarily the absolute best that anyone could achieve.

We realize that these aren't in terms of X-theoretical, as you asked, but we haven't seen any published information that gives benchmark data in terms of X-theoretical. Our general impression is that 3X is good, and that anything in the vicinity of 2X is exceptional. If any other readers know of published resources on this topic, or have any information that you would like to share with our newsletter subscribers on this topic, please let us know. You can email Jennifer.Robinson@FabTime.com.

Individual Tool Cycle Time Benchmark Data

Another subscriber wrote: "Currently, we are working on indices to drive the cycletime down. I am looking for benchmark actual rpt/ theory rpt for each tool. On the whole, direction is driving the fab CT to about 2.5x and 3x, what is not clear to a lot of us is the benchmark figures for tool such as etch, CVD, furnace, wet bench, scanner (especially scanner which has its own WIP). If you happen to have those figure, it will be great if you can share with me."

FabTime response:

Unfortunately, we don't know of any data on cycle time benchmarks by type of tool. We would expect that this varies depending on the type of technology and on the product mix, but we've never seen anything published on this topic. If any readers have non-proprietary information on cycle time benchmarks by tool, we would be very interested in hearing about it, as would the subscriber who originally broached the question. Just send email to Jennifer.Robinson@FabTime.com.

FabTime Characteristic Curve Generator

Introduction

As we have discussed in previous newsletter issues, there are a number of factors that affect cycle time at a particular toolgroup. These include variability in lot arrival times, process time variability, tool utilization and equipment downtime. To allow you to explore the impact of these factors, we've developed an Excel spreadsheet tool for generating individual tool characteristic curves.

Characteristic curves are graphs that show cycle time vs. equipment utilization. They usually display a "hockey-stick" type of shape, with cycle times increasing slowly and almost linearly at low utilization, and then increasing rapidly once the load on the tool exceeds some value. (Batch tools can be an exception to this - see issue 2.1 for details.) Having an idea of the characteristic curve for a tool lets you decide how heavily you should load the tool, based on how high a cycle time multiplier you're willing to accept.

The Excel Spreadsheet Inputs and Assumptions

The Excel spreadsheet that we've developed can be downloaded from www.FabTime.com/charcurve.htm. It contains no macros or add-ins - it simply contains a series of formulas and charts. The spreadsheet relies on a queueing approximation for the average cycle time of a single tool with general arrival and service processes, and a single random failure process. The approximation is most appropriate for per-lot tools, and possibly for per-wafer tools, but probably not for batch or cluster tools. [We originally obtained this approximation from Ottmar Gihr of IBM Germany, with whom we worked on the SEMATECH Measurement and Improvement of Manufacturing Capacity project in the mid-1990s. We later (11/12/01) revised the approximation to clear up an error in the terminology between coefficient of variation and squared coefficient of variation. We also modified the formula slightly, so that it now matches Equation 8.6 in the text Factory Physics, by Hopp and Spearman. This text has been revised to reflect the updated version of the formula.]

There are six input parameters:

- PT = mean value of process time in hours (can be per-lot or per-wafer process time)
- Cs = coefficient of variation of process time
- Ca = coefficient of variation of interarrival times
- Cr = coefficient of variation of the repair process
- MTBF = mean time between failures (in hours)
- PctDown = downtime percentage (mean repair time divided by MTBF)

Process time and mean time between failures should both be entered in the same time units (either hours or minutes). Coefficient of variation is a dimensionless normalized measure of the variation of a process. It consists of the standard deviation of the distribution, divided by the mean. For a constant distribution, the coefficient of variation is 0. For an exponential distribution, the coefficient of variation is 1. When looking at individual tools in a wafer fab, the time between arrivals is usually highly variable, and the coefficient of variation will be near 1. This is because of the large amount of upstream variability, caused by downtimes, setups, batching, hot lots, etc. Process times are usually less variable. However, if you have a tool that processes a number of different recipes, with different process times, this variation in the service process should be captured. The repair process (the time required for successive repairs) will likely also exhibit some variability, if only due to the fact that the repair time effectively includes time spent waiting for someone to come and make the repair after the tool goes down. The failure process (the time to the next failure after each repair) is assumed to be highly random with this approximation, reflecting the fact that a single distribution is being used to account for all downtime on the tool.

The Excel Spreadsheet Outputs

From these input parameters, the calculator derives the following variables:

- MTTR = mean time to repair = PctDown * MTBF
- Av = equipment availability = 1 - PctDown

- RTR = repair time to service time ratio = MTTR/PT
- PT* = process time adjusted by availability = PT/Av
- CV^2 = calculated system variation = Cs^2 + (1+Cr^2)*RTR*Av*(1-Av)
- MaxArr = maximum arrival rate to the system = availability/mean process time = Av / PT

The spreadsheet then generates a series of values for arrival rate, lambda, into the tool. Lambda will be in units reciprocal to process time. You can use either per-lot process time or per-wafer process time, and lambda will then be calculated accordingly. Note that 1/lambda is the average time between arrivals (either lot or wafer arrivals). [The reason that the approximation is more appropriate for per-lot tools is that lots are more likely to arrive one-at-a-time, while wafers usually arrive in groups.]

Then, for values of lambda ranging from near zero (actually, from the value that makes the overall utilization of the tool equal to 50%) up to slightly below MaxArr, the average estimated cycle time is:

CT = PT*[1+((PT*)(lambda))/(1-((PT*)(lambda))))*((Ca^2/2)+(CV^2/2))]

The cycle time values are then normalized by dividing by the average process time, and plotted against utilization for three scenarios.

Example - Repair Time Variability

In the default example in the spreadsheet, we have the following values for parameters for all three scenarios:

- PT = 2
- Cs = 0 (constant process times)
- Ca = 1 (highly variable times between arrivals)
- Cr = 1 (highly variable repair times)

The values for MTBF and PctDown are as follows:

Scenario 1: MTBF = 10, PctDown = 10%
Scenario 2: MTBF = 40, PctDown = 10%
Scenario 3: MTBF = 80, PctDown = 10%

For all three scenarios, AV = .9, PT* = PT/AV = 2.2222, and MaxArr = AV/PT= .9/2 = .45

For scenario 1, MTTR = 1, and RTR = MTTR/PT = 1/2 = .5, and

CV^2 = Cs^2 + (1+Cr^2)*RTR*Av(1-Av) = 0 + (1+1)(.5)(.9)(.1) = 0.09

For scenario 2, MTTR = 4, and RTR = 4/2 = 2, and

CV = 0 + (1+1)(2)(.9)(.1) = 0.36

For scenario 3, MTTR = 8, and RTR = 8/2 = 4, and

CV = 0 + (1+1)(4)(.9)(.1) = 0.72

For lambda = .4275 (slightly below MaxArr), we have

Scenario 1 CT = 25.233
Scenario 2 CT = 30.933
Scenario 3 CT = 38.533

So, what we have here is three scenarios with the same arrival and service processes, and the same total percent time down. The only difference is in the relative size of the downtimes. The first scenario has relatively small (1 hour), frequent (every 10 hours) downtimes, while the third scenario has much larger downtimes (8 hours), and a much longer time between failures (80 hours). The average cycle time of the third scenario, with these larger downtimes, is approximately 60% longer than that of the first scenario.

Implication

The implication of the above example is that if you have a choice between shorter, more frequent interruptions (failures, preventive maintenance, etc) and longer, less frequent interruptions, for which the total downtime percentage is the same, the shorter interruptions lead to lower cycle times.

Of course, for failures you probably don't have a lot of control over MTBF and MTTR. However, for preventive maintenance you do have some control, and the choice may be:

1) Less frequent, longer maintenance events
2) More frequent, shorter maintenance events

To explore the impact of this decision on cycle time, try changing the coefficient of variation for repair times (Cr) to a much smaller number (The length of planned maintenance downtimes is probably more predictable than the length of unplanned downtimes). Then compare the resulting characteristic curves.

In general, longer downtimes add more variability to the system, even though the percentage of downtime is held constant. The overall rule is: the more variability, the greater the impact on cycle times.

Cycle Time Constrained Capacity

An extension to characteristic curves is the notion of cycle time constrained capacity. Cycle time constrained capacity is the throughput rate at which some target cycle time can be achieved. Cycle time constrained capacity is expressed as a multiple of theoretical cycle time (e.g. 3X-capacity is the throughput rate at which average cycle time is three times raw process time). Although the term cycle time constrained capacity is more commonly used for factory cycle time, it certainly applies to individual tool cycle times also. The most practical implication at the tool level is to translate the target cycle time value into a target WIP value (using Little's Law - see Issue 1.3).

Summary

Individual tool characteristic curves can help you to explore the impact of various factors on tool cycle time WIP. We have provided a spreadsheet that automates the calculations for a single tool, and lets you quickly view three different downtime and variability scenarios on one page. Please feel free to use this spreadsheet, and to pass it along to others -- we only ask that you attribute the source, and maintain our copyright notice!

Community News/Announcements

Bob Kotcher

Bob Kotcher offers his services as an industrial engineering manager, highly responsible individual contributor, or consultant. He has an MBA and BSIE and nearly fifteen years of experience in high-tech manufacturing. Bob most recently specialized in wafer fab simulation and process improvement as Manager of Industrial Engineering at Headway Technologies in Milpitas. He can be reached at bkotcher@compuserve.com, (408) 567-0231, or (408) 910-2546.

FabTime Reaches Agreement with Managed Outsourcing, Inc.

Menlo Park, CA. August 6, 2001 - FabTime Inc. today announced that it had reached an agreement with Managed Outsourcing, Inc. (MOI) to use MOI's jTask software in all FabTime training classes. FabTime is a cycle time management system that provides web-based access to fab performance data for fab managers and fab supervisors. jTask is a job task analysis system that makes it possible to mathematically measure the capability of training class attendees. The text of the full press release is available at www.fabtime.com/PRjTask.htm

FabTime Newsletter Reaches 500 Semiconductor Industry Subscribers

Menlo Park, CA. August 21, 2001 - FabTime Inc. today announced that its cycle time management newsletter distribution list had climbed to 500 subscribers. The newsletter is a monthly email publication containing technical articles on wafer fab cycle time management as well as industry news and recommendations. Recent topics have included: the financial benefits of cycle time reduction; overall equipment efficiency (OEE); and cycle time improvement methods for use during a downturn. Other issues have focused on the impacts of variability, theory of constraints, just-in-time manufacturing, single-path tools, batch size decisions, and lot size on cycle time.The text of the full press release is available at www.fabtime.com/PRNewsletter.htm

FabTime Recommendations

Testbed Datasets

We have mentioned the Modeling and Analysis for Semiconductor Manufacturing (MASM) lab at Arizona State University. This month we would like to highlight a set of testbed datasets that is available from the MASM lab. There are currently seven factory-level datasets, derived from actual wafer fabs. The purpose of the datasets is to provide researchers with realistic data for testing simulation and other types of models. These datasets have been in use for several years (most were originally developed at SEMATECH), and have been used by researchers at a number of different universities. If you are looking for data to use for model or algorithm validation, they are a great place to start. The datasets are available from http://www.eas.asu.edu/~masmlab/ftp.htm.

Cost of Cycle Time

For my birthday, I (Jennifer) was given a great new high-tech toy. The Archos Jukebox 6000 is a 6 GB MP3 player and USB hard drive. It's about the size of a regular WalkMan, but you can use it to store something like 150 CDs in MP3 format. Because it's really a USB hard drive, installation is very easy (with Windows 2000, at least - it's not NT compatible) - you simply use Windows Explorer to drag-and-drop MP3 files onto the Jukebox drive. You can also use it as backup portable storage for other types of files. It comes with software for converting your CDs to MP3. So, if you have a long trip coming up, and you want to take all of your CDs, it's something to consider. You can find more information at http://www.archos.com/us/products/product_500096.html.

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