FabTime Cycle Time Management Newsletter

Volume 8, No. 3 April 2007

Information

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

Publisher: FabTime Inc. FabTime sells cycle time management software for wafer fab managers. New features in the software this month include a new Queue Limit Lot List Chart (shows non-held lots in queue, colored green or red depending on a queue time limit) and support for automatic reservation of other lots with same RunSequence upon BeginRun (in dispatch module).

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Welcome

Welcome to Volume 8, Number 3 of the FabTime Cycle Time Management Newsletter. I'm pleased to report that thanks to a strong showing from Maxim Integrated Products, now the company with the most newsletter subscribers, and International Rectifier (new to the top 20 list) the distribution list for FabTime's newsletter now exceeds 2500 people. We've come a long way since the first issue was distributed to 33 people! My thanks to all of you (and especially to the many people from Maxim and IR) for helping to make the newsletter a vibrant industry publication. Frank and I also send our sympathy to the subscribers from Virginia Tech, and grieve with them for the recent tragedy there.

This month we have two community announcements and one response to last month's article about making morning meetings more effective. Our FabTime software user tip of the month is about tracking cumulative hold time across lots. In our main article this month we discuss the reasons for needing planned operation-level cycle time values, and review several potential methods for generating them. Methods discussed include using a straight multiple of theoretical, across all steps, using queueing or simulation models to estimate step-specific values, and using actual historical data. We then discuss some technical issues related to the use of actual data, specifically the selection of using mean or median value from a set of actual observations. We hope that you will find this discussion useful.

Thanks for reading!—Jennifer

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Community News/Announcements

2007 ISMI Manufacturing Productivity Symposium

We received the following call for papers, which we have shortened slightly:

4th Annual ISMI Symposium on Manufacturing Effectiveness

October 24-25, 2007 • Austin, Texas

Be a part of this year's ISMI Symposium on Manufacturing Effectiveness—an event that has emerged as one of the industry's "can't miss" meetings on productivity in microchip manufacturing! The Symposium is the centerpiece of ISMI Manufacturing Week, which begins Oct. 22 with two days of real-world workshops and tutorials on leading-edge technologies, all aimed at making your company more competitive.

This year's Symposium theme—Productivity in Depth—will drive a calendar of leading-edge presentations on fab and equipment productivity, yield and metrology, environmental design, simulation and modeling, and lean manufacturing—plus informative rounds of supplier exhibits and poster sessions.

Your paper or poster will reach hundreds of international technologists at what industry writer Tom Cheyney has called "one of the top three conferences focused on both the high-level statistics-driven and practical nitty-gritty aspects of chip manufacturing."

Like previous meetings, this year's ISMI Symposium will be oriented to semiconductor manufacturing professionals eager to discover the strategies of achieving more productivity at lower cost. More information about the ISMI Symposium on Manufacturing Effectiveness, including hotel and logistics, can be found at http://ismi.sematech.org-/ismisymposium.

Presentations are being solicited on the following topics, among others:

- Process-related productivity improvement activities
- Yield modeling and yield improvement methodologies
- Real-time data collection and management
- Activities to achieve fast cycle time
- Real-time factory/equipment data management
- Lean Manufacturing (new session this year)
- Equipment-related productivity improvement activities
- Factory productivity optimization using simulation
- Factory scheduling, dispatching optimization
- e-Manufacturing implementations
- Novel approaches to the analysis and visualization of manufacturing data

Submission Guidelines: Abstracts must be submitted electronically using the form found on the ISMI Symposium website.

Abstracts submission period: April 2-June 22

Notification of paper or poster acceptance: July 2

Final presentation due: October 1

Fab Owners Association Attracts New Device Maker Members

Cupertino, CA – March 28, 2007 — The Fab Owners Association (FOA), the association of semiconductor / MEMS manufacturing executives and suppliers, has announced the addition of two new device maker members, Microchip Technology Inc. (NASDAQ: MCHP), a leading provider of microcontroller and analog semiconductors, and Skyworks Solutions Inc. (NASDAQ: SWKS), an innovator of high performance analog and mixed signal semiconductors.

"Microchip Technology's continuous improvement culture and systems have resulted in industry-leading yields across all of our fabs, and short lead times for our broad range of customers around the world," said Dave Lambert, vice president of Microchip's Fab Operations. "We are joining the FOA's membership to exchange best-practice knowledge, as part of our relentless drive to further optimize cycle times and exceed customer expectations."

Terry Pope, Skyworks Solutions vice-president of semiconductor manufacturing said, "I believe it is still possible to be competitive with semiconductor manufacturing in the United States. To do this requires that companies take advantage of every opportunity to reduce input costs, maximize efficiency of fab tools, and minimize the cost to maintain top factory performance. The Fab Owners Association provides a forum for best practices, as well as an opportunity for aggregated efficiencies. Member participation is an advantage."

"The addition of multiple new members like Microchip and Skyworks over the past year has created a compelling gravity to the FOA as an organization," stated L.T. Guttadauro, FOA executive director. "By attracting new device makers and suppliers, we can improve the value of our benchmarking data, survey capabilities and collaborative purchasing power for all members."

Additionally, Excimer Laser Repair Corp. and MAX International Engineering Group have joined as associate members.

The FOA's device maker members are the following companies: AMI Semiconductor, Cypress Semiconductor, Delphi Microelectronics Center, Fairchild Semiconductor, Freescale Semiconductor, International Rectifier, Intersil, Jazz Semiconductor, MagnaChip Semiconductor, Micrel Semiconductor, Microchip Technology, NXP, ON Semiconductor, Skyworks Solutions, Spansion, and ZMD AG.

FOA device maker member companies represent approximately 1,000,000 8-inch-equivalent monthly wafer starts and over US$24 Billion in annual revenue.

FabTime is an associate member of the FOA. FabTime's Jennifer Robinson will be attending the next FOA meeting, to be held in Austin, Texas on April 25th and 26th.

FabTime User Tip of the Month

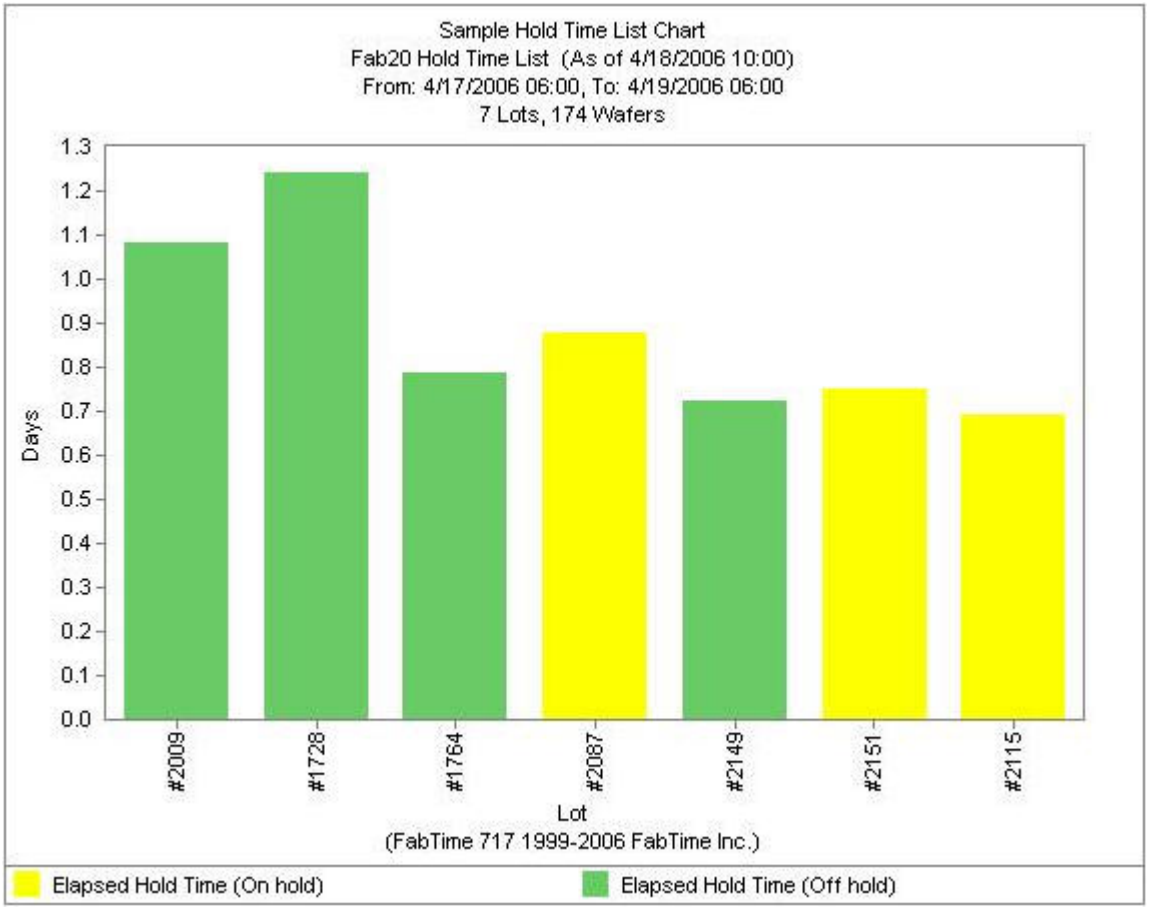
Track Total Hold Time across Lots

Do you need to keep better track of your holds? You can use the new Hold Time Charts in FabTime to look at trends in total hold time across lots, as well as time on hold for individual lots. You can find the new Hold Time Charts on the Chart list, immediately below the WIP charts. Press "Show" to display the hold chart names, if they are not already displayed, and then press the "Go" button next to Hold Time Trend. The resulting chart displays, for each time period (usually days), the total amount of time that lots

spent on hold during that period (the yellow bars). The black line shows average hold duration (against the right-hand axis). This allows you to look for patterns in amount of hold time. You can slice any of the periods by other attributes, such as operation or hold code, to look at a pareto version of the data. To do this, simply select your desired "slice by" variable (e.g. "Hold Code") for any row of the data table, and then click the plus/magnifying glass sign. This allows you to look at total amount of hold time spent during some time period broken out by hold code, for example. You can, of course, filter these charts as necessary (e.g. to look at hold time for hot lots, or for a particular product family).

If you drill down from the Hold Time Trend chart by clicking the "List" link in the data table for any of the rows, you'll see a list of all holds that occurred at any point during that time period. The lot name is shown on the x-axis. The height of each column indicates how long the hold was, while the color (yellow or green) tells you whether or not the lot is still on hold for that hold transaction (green bars indicate holds that occurred during the time period that have since ended). If a lot went on hold multiple times, you'll see a separate bar for each time that the lot went on hold. You can use the Hold Time Pareto chart, sliced by Lot, to see the cumulative time that a particular lot spent on hold, across multiple hold instances. From the Hold Time List chart you can, naturally, drill down to see a history of any of the lots, to view the impact of the hold on the entire lot cycle time.

If you have any questions about this feature (or any other software-related issues), just use the Feedback form in the software.



Subscriber Discussion Forum

Issues 8.02: What Makes an Effective Morning Meeting?

Moose Haas of Micron submitted the following feedback to last month's main article about morning meetings:

"To me the most important aspects of any meeting are threefold:

1. Clearly understood meeting goal(s)—what's the purpose of this meeting? Too many times in too many forums (from operators to Board Members) meetings are called for meeting's sake!

2. Clearly delineated meeting roles--who speaks, who listens, and who has authority to task others. In the Air Force we called it "He who owns the pens" (dry erase markers)--someone must lead the meeting and have the responsibility and authority to achieve the goals set above....

3. Clearly defined action items with no ambiguous Action Item ownership and definite due dates--how many times have you left a meeting wondering "What was that all about?" and/or "What do we do next?"

My paltry two cents.... Thanks for having this great resource and keep up the good work!"

FabTime welcomes the opportunity to publish subscriber-suggested discussion topics. Send your questions or comments to newsletter@FabTime.com.

Estimating Planned Operation Cycle Times

There are various reasons why fabs need planned operation cycle time data. Chief among these is for use by critical-ratio type dispatch rules (which try to accelerate lots that are behind schedule according to a set due date). Planned cycle times are also used for projecting when individual lots will ship and for forecasting cumulative outs over some future time window.

One common way that fabs obtain planned cycle time data is by simply multiplying theoretical operation cycle times (process times) by a standard multiplier, known as an x-factor. Three is quite commonly used in the industry, such that overall cycle time is planned to be three times the cumulative process time, though of course other multiplier may be used. As long as the multiplier used is one that reflects the fab's current ability to perform, this usually gives a reasonable first pass.

However, sometimes a more detailed approach is needed. Not all operations run at the same multiple of theoretical process time. Typically we plan for bottleneck tools to have longer queue times (and hence to run at higher multiples of theoretical), while we make up the extra time at other non-bottleneck steps. So how can we make

this data more accurate?

One approach is to use queueing or simulation models to estimate the proper x-factor for an operation. There are, however, problems with this approach, due to the need to maintain detailed models with a variety of inputs. A more straightforward approach is to use historical data to estimate operation cycle times. The question then becomes, how best do we make this calculation? In the remainder of this article, we will discuss methods for estimating planned operation cycle times.

Queueing Models

It is possible to use queueing models to estimate the x-factor for a particular operation. The recommended inputs include:

- Number of tools that can be used for the operation
- Average tool utilization
- Average process time
- Variability assumptions (coefficient of variation of both times between arrivals and process times)

FabTime has developed spreadsheet based tools that incorporate queueing models, can be used to estimate x-factor. Our freely available cycle time characteristic curve generator can be downloaded from www.fabtime.com/charcurve.shtml. A more advanced version, with additional inputs, is reserved for use by our software and training class customers.

Queueing models, however, are better for looking at relative answers and understanding the general impact of changes in operating practices, than they are at estimating specific planned cycle times. The models that we've assembled do not account for batch tools or operator constraints, and are quite sensitive to assumptions about utilization and level of variability at the tool. In most cases, it will be easier to collect actual operation cycle time data than to collect the inputs needed for operation-level queueing models. Therefore, while we think that such queueing models are excellent teaching tools, useful for building intuition, and looking at the relative effects of different parameters, we don't generally recommend their use for making operation-level cycle time estimates for dispatch systems.

Simulation Models

One can also use full-fab simulations for generating estimates for per-operation cycle times. Simulation models can be endlessly detailed, and can capture the effects of batch tools, reentrant flow, operator delays, rework, etc. The problem with using simulation models for this purpose is that building a model that's accurate enough to realistically represent the cycle time at each operation requires construction of a very detailed model. This in turn requires collection of a considerable amount of data. Maintaining such a detailed model, unless your fab has a way to automatically extract model data from the MES, can be a full-time job, requiring specially trained personnel. Data in a fab changes rapidly, from product mix changes, new tools being brought online, new products, etc., making full fab simulation models difficult to keep up to date. While we think that simulation can be a useful tool for understanding the complex behavior, as in the case of queueing models, we believe that collecting actual cycle time data will require considerably less work than collecting data to populate a simulation model.

Historical Data

Thus it appears that the most practical solution for obtaining per-operation cycle time estimates is to use actual historical data. There are limitations to this approach, of course, particularly when dealing with new operations for which there is no historical data. Because of the ever-changing nature of the fab, you'll need to decide what time frame to use for

your historical estimates, and how frequently to update them.

You will also be reliant on the accuracy of data logging in your fab. To estimate per-operation cycle times from actual data, it is necessary that your operators (or your automated tools) log operation move-outs at the detailed step level (as opposed to logging some aggregated multi-step move-out only). The time from move-out of the prior operation to move-out of the current operation is the current operation's cycle time. You don't need to log move-ins (or start process transactions) if all you want is the overall estimated step cycle time. Of course if you do want to break this up into queue time vs. process time, then you'll need your people or tools to log start process transactions also.

Assuming that you have the historical per-operation cycle time data, the next decision is what method to use for aggregating it. A seemingly logical approach is to take the set of actual observations of data for each operation, and then use the median. The median is the value for which half of the observations are higher, and half are lower. Medians are known to be less influenced by outliers than averages, and appear on first glance to be the best choice for this type of data.

However, we looked at this for some actual fab data, and found that use of medians for per-operation cycle time data resulted in projected overall cycle times being significantly lower than expected. So we explored this question in more detail, and asked: is the sum of the medians (what we get when we add up the planned operation cycle times for a route, when the values are based on medians) equal to the median of the sums (the median factory cycle time for shipped lots for the same route)?

We consulted with a statistics professor (Dr. Beth Chance of Cal Poly), and thought about examples and counter-examples. We very quickly we came up with the following counterexample... numbers in the columns Op1, Op2, Op3, Op4, Op5 are cycle times for a particular lot at that operation.

Lot	Op1	Op2	Op3	Op4	Op5	TotalCT
L1	20	1	1	1	1	24 days
L2	1	20	1	1	1	24 days
L3	1	1	20	1	1	24 days
L4	1	1	1	20	1	24 days
L5	1	1	1	1	20	24 days
Medians	1	1	1	1	1	24 days

So in this case, sum(medians) = 5 days, median(sum) = 24 days. They are clearly not equal!

The reason that average and median are not equal in the above example is because the data is not evenly distributed. There are many low values, and then a few high values that pull up the averages. Using the median on data that is distributed like this will tend to underestimate the total cycle time.

Similarly, we can construct scenarios where the use of medians will tend to over-estimate the cycle time, though these may be less representative of actual fabs. This behavior will occur with bi-modal sorts of distributions, where the majority of the data has high values, but a significant minority are much smaller. For example, suppose that the five observations are 100, 80, 80, 1, and 1. The median is 80, but the average is 52.4. If we add this up over several similar steps, we'll see a significant difference in the estimates for cycle time. In either case, sum of the median estimates will not be a good predictor of overall cycle time.

Medians are useful for some things, and they are in fact more resistant to outliers than are averages. However, from looking at examples like this, and from observing this data for an actual fab, we've concluded that medians have properties that don't match our intuition. This is because our experience is based mostly on thinking about averages. This analysis suggests that we shouldn't use median cycle times for planned operation cycle time data, if we want to then add up those planned cycle

times to get an estimate for total factory cycle time. We are much better off using averages of the actual per-operation cycle times of individual lots.

Side-Note for FabTime Software Users

If you use FabTime, and would like to review historical estimates for operation-level cycle time, you can use the Operation Cycle Time Pareto chart (located under Operation Cycle Time charts on the Chart page). Simply generate the chart, change the from date to give you a wider window of historical data (maybe a month), and change the slice-by variable to "Operation". You can change the sort order for either the chart or the data table, to view the operations in order (select "Object Sequence" from the first sort drop-down, and make sure that the "Desc?" box for sorting in descending order is not checked.

If you would like to get a feel for the distribution of your per-operation data, clicking on "List" in the Lots column of any of the rows in the data table will take you to the Moves Lot List chart for that operation. This chart shows cycle time, queue time, and process for each move completion. You can export the data table to Excel to analyze the data in more detail.

If you would like us to do an extract for you, to feed actual average historical data back in for you, in the form of planned cycle times, just let us know.

Conclusions

There are many uses for planned operation cycle time data. Planned cycle times can be useful in due-date performance-based dispatching, predicting output dates for individual lots, and forecasting the number of outs over a given time period. Fabs use a variety of methods for estimating per-operation cycle times. The most common approach is to apply a straightforward multiplier of theoretical process time to all of the steps in a flow. However, this approach may not offer enough detail, and fabs may need to estimate step-specific cycle times. While it is possible to use queueing or simulation models for preparing these estimates, those approaches require a high degree of actual data to be accurate. In most cases, it's better to simply collect actual historical data for the per-operation cycle times, and average across a set of lots. We don't recommend taking the median of a set of historical data in this case, because the sum of the medians may not accurately reflect that overall average cycle time, because of the way this type of data is often distributed.

Acknowledgements

Many thanks to Rudy Prakash of Peregrine Semiconductor for discussions on this topic, in particular the question of means versus medians for estimates based on historical data.

Closing Questions for FabTime Subscribers

How do you estimate operation-level cycle times in your fab? Do you use the same x-factor for all operations, different x-factors obtained from analytical models, or actual historical data?

Subscriber List

Total number of subscribers: 2589, from 471 companies and universities. 22 consultants.

Top 20 subscribing companies:

- Maxim Integrated Products (157)
- Intel Corporation (155)
- Micron Technology, Inc. (87)
- Analog Devices (74)
- ATMEL (74)
- Infineon Technologies (65)
- Freescale Semiconductor (62)
- Cypress Semiconductor (58)
- International Rectifier (57)
- STMicroelectronics (57)
- Texas Instruments (56)
- X-FAB Inc. (54)
- NXP Semiconductors (51)
- Chartered Semiconductor Mfg (48)
- ON Semiconductor (48)
- TECH Semiconductor Singapore (47)
- IBM (37)
- Seagate Technology (33)
- Spansion (32)
- BAE Systems (30)

Top 5 subscribing universities:

- Virginia Tech (11)
- Ben Gurion Univ. of the Negev (7)
- Arizona State University (6)
- Nanyang Technological University (5)
- University of Texas (5)

New companies and universities this month:

- Alphasem AG
- Eugene Tech
- First Solar
- Hifn
- Hutchinson Technology
- Motorola
- Rose-Hulman / GE Healthcare
- ScheduleSource
- SinoMOS

Note: Inclusion in the subscriber profile for this newsletter indicates an interest, on the part of individual subscribers, in cycle time management. It does not imply any endorsement of FabTime or its products by any individual or his or her company.

There is no charge to subscribe and receive the current issue of the newsletter each month. Past issues of the newsletter are currently only available to customers of FabTime's web-based digital dashboard software or cycle time management course.

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FabTime® Cycle Time Management Training

"It was helpful to see best-in-class methods for wafer fab cycle time management. Discussing these matters in-depth with you was quite valuable, as we could ask questions specific to our fab and processes."

Shinya Morishita
Manager, Wafer Engineering
TDK Corporation

Course Code: FT105

This course provides production personnel with the tools needed to manage cycle times. It covers:

- Cycle time relationships
- Metrics and goals
- Cycle time intuition

Price

$7500 plus travel expenses for delivery at your site for up to 20 participants, each additional participant $300.

Interested?

Contact FabTime for a quote.

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Do you make the best possible decisions?

- Do your supervisors possess good cycle time intuition?
- Are you using metrics that identify cycle time problems early?
- Can you make operational changes to improve cycle time?

FabTime's Cycle Time Management Training is a one-day course designed to provide production personnel with an in-depth understanding of the issues that cause cycle time problems in a fab, and to suggest approaches for improving cycle times. A two-day version is also available upon request.

Prerequisites

Basic Excel skills for samples and exercises.

Who Can Benefit

This course is designed for production personnel such as production managers, module managers, shift supervisors, hot lot coordinators, and production control.

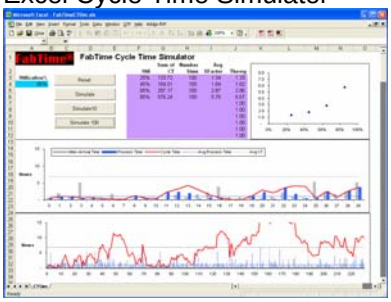
Skills Gained

Upon completion of this course, you will be able to:

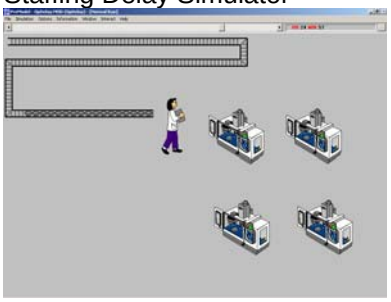
- Identify appropriate cycle time management styles.
- Teach others about utilization and cycle time relationships.
- Define and calculate relevant metrics for cycle time.
- Teach others about Little's law and variability.
- Quantify the impact of single-path tools and hot lots.
- Apply cycle time intuition to operational decisions.

Sample Course Tools

Excel Cycle Time Simulator



Staffing Delay Simulator



Additional Half-Day Modules

- Executive Management Session.
- Site-Specific Metrics Review.
- Capacity Planning Review and Benchmark.