FabTime Cycle Time Management Newsletter

Volume 7, No. 6 July 2006

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 this version (2006) include .NET 2.0 framework and support of wildcards in the ToStep filter on Forecast Outs charts.

Editor: Jennifer Robinson

Contributors: Billy O'Donnell (National Semiconductor); Alfred Roess (Texas Instruments)

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Welcome

Welcome to Volume 7, Number 6 of the FabTime Cycle Time Management Newsletter! I hope that you're all having a great summer. In this month's issue we have an announcement about my being named to the Supplier Advisory Board for the Fab Owners Association. The FOA is a corporation of semiconductor fab owners and associates who meet to discuss common manufacturing issues, and to combine strengths and resources. I recommend that you look into it, if you are an independent device manufacturer. We also have announcements for two upcoming industry conferences.

This month's FabTime software user tip of the month describes how to use our new Forecast Outs Lot List chart. In our subscriber discussion forum we have a response from Billy O'Donnell at National Semiconductor about an attempt to implement Kanban cards in a wafer fab (in response to last month's article about lean manufacturing). We also have a subscriber question from Alfred Roess at TI about making active dispatching decisions to improve downstream batch efficiency. We welcome your feedback regarding these topics, or your other manufacturing-related questions.

In our relatively short main article this month, we discuss a fundamental conflict in wafer fabs: the pressure to simultaneously increase tool utilization, while decreasing cycle time. As regular readers of this newsletter know, utilization is one of the main drivers of cycle time at the tool level. As utilization increases, cycle time increases non-linearly, becoming very large for tools with the highest utilization values. Despite this fact, fabs are under cost pressure to increase utilization, so that they can get more throughput out of the same toolset. In this article, we discuss two ways to resolve this conflict.

Thanks for reading!—Jennifer

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Community News/Announcements

FabTime's Jennifer Robinson Named to FOA Supplier Advisory Board

FabTime's **Jennifer Robinson** was recently named to the supplier advisory board for the Fab Owners Association (FOA). The FOA is an international, nonprofit, mutual-benefit corporation of semiconductor fab owners and associates who meet regularly to discuss and act on common manufacturing issues, combining strengths and resources to become more competitive. Device manufacturer members of the FOA currently include AMIS, Cypress, Delphi, Fairchild, Freescale, Intersil, Jazz, LSI Logic, MagnaChip, Micrel, Philips, ON Semi, Spansion, and ZMD AG. FabTime is an associate member of the FOA. The other supplier advisory board members are Marc Schweitzer of Tara Technologies and Chris Noe of Macquarie Electronics, along with FOA Executive Director L.T. Guttadauro and FOA Secretary and Treasurer Gene Norrett. You can find more information about the FOA at www.waferfabs.org/.

Conference Announcement: ISSM 2006: September 25-27

The 2006 International Symposium on Semiconductor Manufacturing (ISSM 2006) will be held September 25th to 27th at the Century Hyatt in Tokyo, Japan. ISSM is the industry's largest forum of semiconductor manufacturing professionals dedicated to sharing technical solutions and opinions on the advancement of manufacturing science. The highlight topics of ISSM 2006 include, process control maturation, application of Taguchi Method, DFM-total optimization for 65nm and beyond, systematic productivity improvement, fab extendibility and flexibility, application-specific semiconductor manufacturing, SiP, 3D modules, Environmental and safety, nanometer-level contamination control, challenges for 450mm fab, and new business model to meet with time-to-market. ISSM 2006 provides an exciting opportunity for all semiconductor professionals to network and share information on the world of manufacturing. The Society of Applied Physics of Japan, IEEE Electron Devices Society, and Semiconductor Equipment and Materials International (SEMI) offer ISSM as a forum to broaden semiconductor manufacturing knowledge. More information is available at www.issm.com.

Conference Announcement: The Third ISMI Symposium on Manufacturing Effectiveness: October 9-11

The third annual ISMI Symposium on Manufacturing Effectiveness will be held Hilton Austin Airport in Austin Texas on October 9th to 11th. Participants will share information and methodologies for reducing manufacturing expenses in both existing and next-generation fabs through advances in equipment, process, resources, fab design, and manufacturing methods. Challenges will be addressed in several parallel sessions dealing with fab and equipment productivity, ESH, fab design, defect inspection, statistical methods, modeling and simulation, and e-manufacturing. The Symposium will offer papers from selected ISMI projects and leading device and equipment manufacturers. Also planned is a discussion by industry experts on the status of 300 mm Prime and 450 mm wafer transition. For more information, see ismi.sematech.org/ismisymposium/.

FabTime welcomes the opportunity to publish community announcements. Send them to newsletter@FabTime.com.

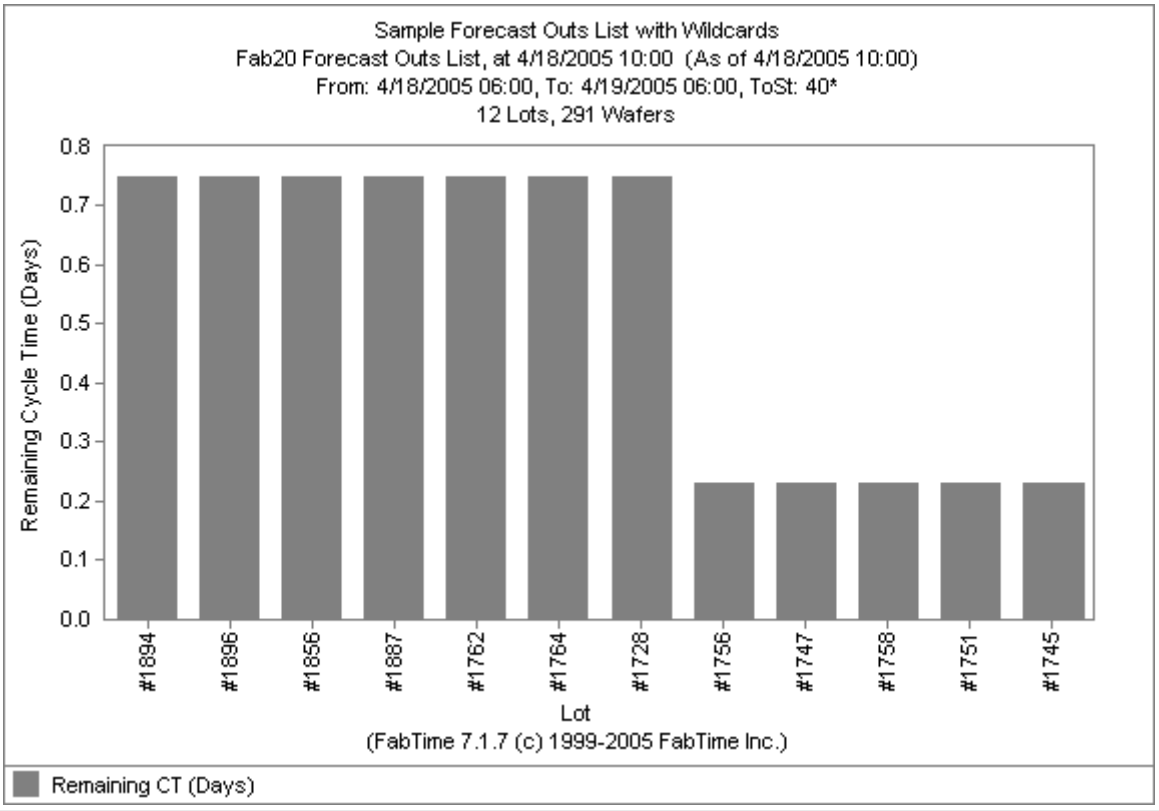
FabTime User Tip of the Month

Use the Forecast Outs Chart to Predict which Lots Will Complete A Target Step

A relatively new feature in FabTime is the Forecast Outs Lot List chart (and accompanying Trend and Pareto versions). The Forecast Outs Lot List chart displays a list of lots that are estimated to complete a target step within the time period specified on the chart. To use the Forecast Outs Lot List chart, your site must have planned cycle time data per step included in FabTime (usually imported from your MES). If this data is available, simply click "Go" next to the Forecast Outs Lot List chart to get to the detailed chart page, and then enter the name of the Step of interest in the "ToStep" filter (wildcards are allowed). The ToStep entry defines the target step that lots must complete to qualify as an out for the chart. Normally this target step is near the end of the line, e.g. you are forecasting shipments. However, you may enter a step anywhere in the line to look at movement through this target step.

The target is specified as a step rather than an operation because each step must be unique within a flow. You should then enter any WIP filters that you need (e.g. to filter by Owner), and revise the From and To dates as required, to select your window of interest. FabTime will then estimate a forecasted out time for each lot that matches the filters set on the chart, and display those lots for which the forecast out date falls within your specified From/To window. The forecast out date is obtained by summing the planned cycle times for all steps in the flow between the lot's current step and the ToStep. The accuracy of this chart depends, of course, on the accuracy of your planned step cycle times.

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

Lean Manufacturing and Wafer Fabs

Billy O'Donnell from National Semiconductor sent in some feedback regarding last month's article about lean manufacturing. He said: "We've not tried to implement lean in a formal way, but did have an effort a few years back to use Kanban to drive down CT. We had some limited success with it, but found the re-entrant flows, and the various issues you'd expect with batch tools feeding single wafer tools with >250 routes in fab. The real killer was the balance between low wip, and the need for high OEE on bottle neck tools, and stability of tool uptime. We abandoned it, as we pushed closer to capacity, and found it was causing us to starve tools which could run, only to find we couldn't run them when we needed to."

Pre-Furnace Process Batching Optimization

Alfred Roess from Texas Instruments asked the following question about making dispatching decisions that account for downstream batch efficiency. He said "We have been developing our dispatch system for several years and need to understand which is the best batch to process in our furnaces. Going through the past FabTime newsletters, I found two approaches, Minimum Batch Size policies (Issue 2.1), and Time Saved > Time Delayed (Issue 3.8). Both are passive approaches.

I would like to ask if there is an active way of preparing lots at least one step in advance. Our interest is typically regarding a clean-up process on single lot wet benches. The question for manufacturing is: which lot should I process in the wet bench next to achieve a good batch in subsequent furnace processes? We have to consider high runner and low runner furnace recipes. In addition, not all subsequent processes of the wet bench are furnace processes. Do you know of approaches or literature on this question or can you ask the community for their experience?"

FabTime Response: We do treat batching optimization in the active manner that you discussed in our FabTime software. We have a flexible next step dispatching rule that can take into account downstream batch optimization, among a variety of other factors. However, we don't have any formal papers that describe this rule in detail – the exact implementation is specific to our customer sites. You can find some general descriptive information about our dispatching module in newsletter 6.4, and in the information sheets for our dispatching module. We don't know of other papers on this topic, but we are including it as a question here for the FabTime newsletter community. Any thoughts on making dispatching decisions to improve downstream batch formation?

FabTime welcomes your subscriber discussion questions and responses. Send them to newsletter@FabTime.com.

Resolving the Cycle Time vs. Utilization Conflict

Introduction

In this month's issue, we take a step back to fundamentals, to discuss the inherent conflict between cycle time and equipment utilization in wafer fabs. Because fab equipment is so expensive, fabs are under constant pressure to increase tool utilization (to get more throughput out of the same equipment set, and hence make more money). Fabs are also under constant pressure to decrease cycle time, to get products out more quickly, and hence make more money. To improve cycle time, fabs need to decrease tool utilization. Some standby time is needed on the tools, to keep cycle times reasonable. When this standby time gets squeezed too much, cycle times can become very high. The more standby time that can be provided, the better cycle times will be.

It's a bit of a Catch-22. To improve throughput, we need to increase tool utilization. To improve cycle time, we need to decrease tool utilization. These two primary fab goals are in direct conflict with one another. This, needless to say, puts considerable pressure on the people who manage wafer fabs.

There are, fortunately, two ways to resolve this conflict:

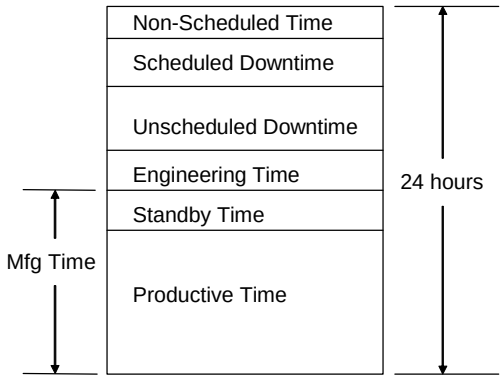
1. Improve equipment uptime, thus extracting standby time from current unavailable time, while maintaining throughput targets.

2. Reduce fab variability.

These two methods of resolving the cycle time vs. utilization conflict will be discussed in the remainder of this article.

Improving Equipment Uptime

Cycle time is directly and non-linearly related to tool utilization, where Utilization = Productive Time / (Productive Time + Standby Time), as shown below. As standby time becomes small relative to productive time, cycle time increases. We could, of course, lower utilization by reducing the amount of productive time. However, this won't help us with our other goal of increasing throughput, and is not usually a good long-term plan. We can also reduce utilization by maintaining the same amount of productive time, while increasing the amount of standby time. And the place to get this extra standby time is obviously to take it out of non-value-added time, particularly unscheduled downtime.



Utilization = Productive Time / Mfg Time

For example, suppose that we have a one-of-a-kind bottleneck tool that is down for an average of 16.8 hours a week (10% of a 168 hour week), and is busy processing wafers for an average of 140 hours a week. This leaves 11.2 hours a week of standby time (assuming no other capacity losses). The utilization of this tool is Productive Time / (Productive Time + Standby Time) = 140/(140+11.2) = 140/151.2 = 92.6%. A rough estimate for the per-visit cycle time through this tool is 1 / (1 - Utilization) = 1 / 0.074 = 13.5X. So, 12.5 hours of queue time, on average, for every hour of process time for each visit to the tool.

Suppose now that we are able to improve the availability of this tool, reducing the downtime from 16.8 hours to 8.4 hours (5%), while maintaining the same amount of productive time. Our new standby time will be 19.6 hours, and our revised utilization will be 140/(140+19.6) =

140/159.6 = 87.7%. Our revised cycle time estimate for this tool will be 1 / (1 - .877) = 1 / 0.123 = 8.1X. Or, about a 40% reduction in cycle time per visit through this bottleneck tool.

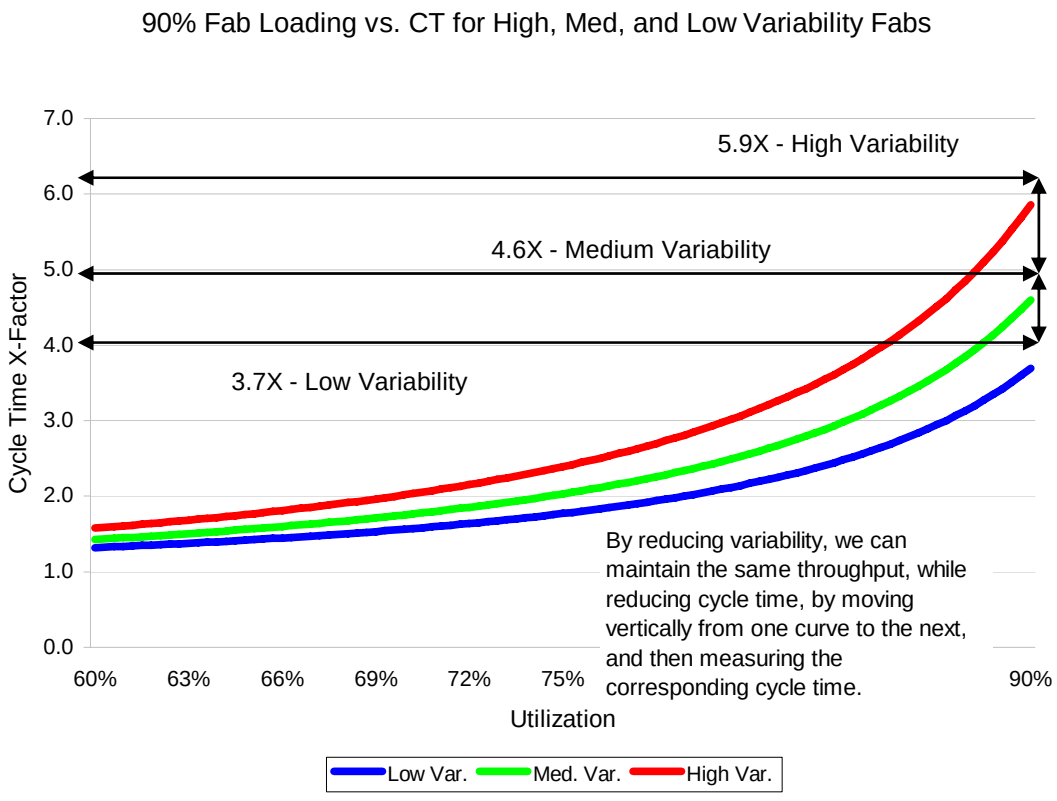
This example is particularly dramatic, because it is a one-of-a-kind tool with a high utilization. However, we can expect to see cycle time reductions of some magnitude from ANY improvement that cuts down on the amount of non-value-added time, and replaces it with standby time.

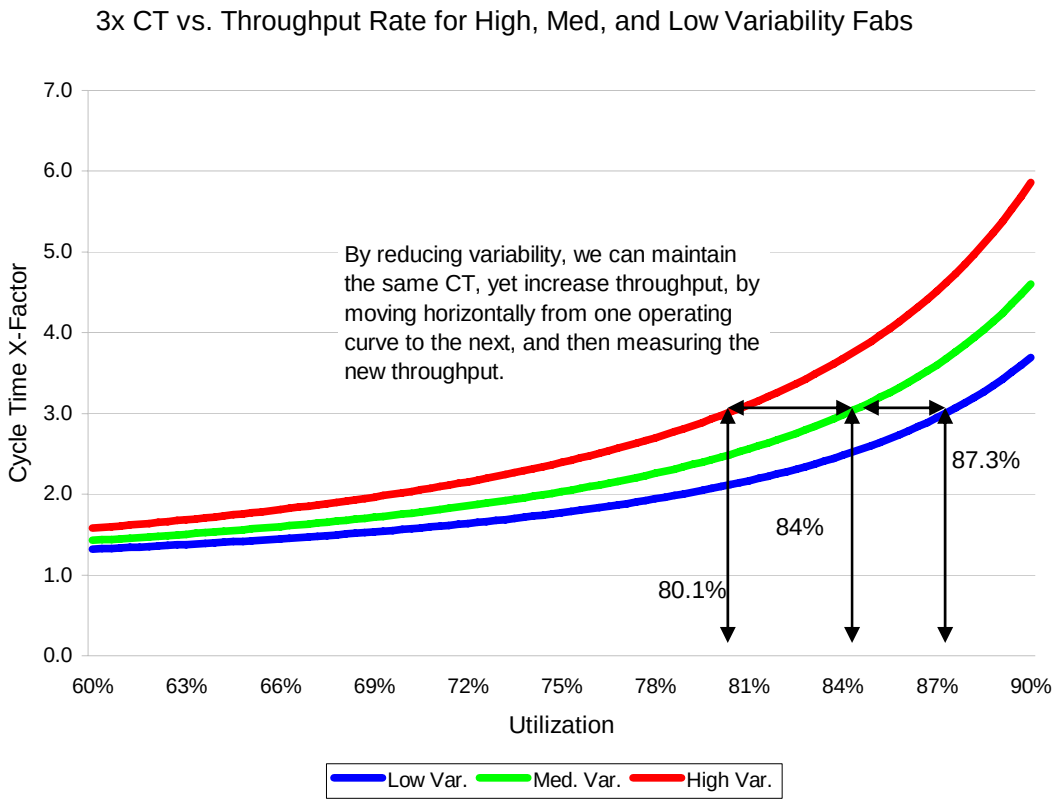
Monitoring Performance: Most fabs are focused on improving availability. However, they may also be reporting and attempting to increase tool utilization. Our recommendation in this area is NOT to try to increase tool utilization on tools that have cycle time issues. Instead, we recommend striving to maintain throughput (or productive time) through the tool, while working on increasing availability. This will result in a lower utilization for the same amount of throughput, and hence improved cycle time.

Decreasing Fab Variability

We have spoken time and time again in this newsletter of the impact of variability on cycle time. Variability in both how things arrive to tools and in how things are processed on tools tends to increase cycle time. Anything that can be done to reduce variability will improve cycle time. If we look at the operating curve (the graph of cycle time x-factor vs. utilization) for a particular piece of equipment, the exact shape of the curve depends on the amount of variability through that tool. When we lower the variability through the tool, we cause the operating curve to shift downward and to the right, so that we achieve either:

- Lower cycle time for the same utilization (as shown below); or
- The same cycle time at a higher utilization (as shown on the next page).





As we have discussed previously (see Issue 6.10, for example), there are many ways to target variability in the fab, including the following:

1. Reduce transfer batch sizes between steps.

2. Run batch tools under a greedy policy, instead of always waiting for them to be full.

3. Smooth the flow of arrivals into the fab (more frequent, smaller batches released).

4. Separate maintenance events instead of grouping them (to minimize the likelihood of having long periods of unavailability).

5. Minimize the number of distinct tools for which each operator is responsible, and stagger break schedules.

6. Reduce the number of hot lots in the fab, especially hand-carry lots.

7. Check setup avoidance policies to make sure that low volume lots aren't waiting too long, especially on non-bottlenecks.

8. Identify and eliminate single path operations (if possible), because variability disproportionately affects single path operations.

Monitoring Performance: Arrival variability to tools can be quantified by measuring the coefficient of variation of the time between arrivals (see Issue 4.1). Coefficient of variation for a series of numbers is the standard deviation of the numbers (how far they are spread out from an average), divided by the average. Measuring coefficient of variation may be especially worthwhile at bottleneck and/or one-of-a-kind tools.

Alternatively, you can measure your success in reducing variability indirectly, by measuring fab cycle time. If you can improve your overall cycle time, while maintaining the same throughput rate and availability values, then you must be reducing variability. A short-term metric that reflects current cycle time improvement is Dynamic X-Factor.

Dynamic X-Factor records, at any point in time, the total WIP in the fab divided by the WIP currently running on tools. A higher DXF means that more WIP is sitting in queue, while a lower DXF means that more WIP is being processed. Short-term reductions in DXF will, if maintained, eventually be reflected in long-term improvements in overall cycle time.

Conclusions

The fundamental conflict faced by people in fabs is the simultaneous pressure to increase equipment utilization while decreasing cycle time. Because factory dynamics dictate that cycle time will increase with increasing equipment utilization, most fabs struggle with these conflicting pressures. There are, however, two ways that we know of to break this conflict. The first is to maintain equipment throughput while improving availability, which will decrease utilization, without a penalty in throughput. This will improve cycle time while maintaining fab output. The other approach is to reduce variability in the fab, which either results in decreased cycle time at the same utilization or allows the fab to increase utilization, while maintaining cycle time. In both cases, the proper selection of metrics can help with implementation.

Closing Questions for FabTime Subscribers

How do you resolve the cycle time vs. utilization conflict in your fab? Do you monitor utilization or availability? Is there pressure in your fab to increase utilization, and simultaneously decrease cycle time?

Further Reading

- J. Robinson and F. Chance, "Operational Recommendations for Wafer Fab Cycle Time Improvement," *FabTime Newsletter*, Volume 6, No. 10, 2005.
- J. Robinson and F. Chance, "Quantifying Wafer Fab Variability," *FabTime Newsletter*, Volume 4, No. 1, 2003.
- J. Robinson and F. Chance, "The Three Fundamental Drivers of Fab Cycle Time," *FabTime Newsletter*, Volume 6, No. 5, 2005. (The article discusses the three fundamental drivers of cycle time at the tool level: utilization, variability, and number of qualified tools per tool group.)
- D. Siems, "Cycle Time and the Core Conflict," *FabTime Newsletter*, Volume 3, No. 4, 2002. (This article represents Dan's thoughts on a core conflict that often exists in managing wafer fabs - trying to get lots out quickly, but having to frequently stop the lots for quality checks. Dan proposes the elements that he believes must exist to weaken this conflict, and maintain good cycle times over the long term.)

Subscriber List

Total number of subscribers: 2137, from 454 companies and universities. 23 consultants.

Top 10 subscribing companies:

- Intel Corporation (129)
- Analog Devices (75)
- Atmel Corporation (66)
- Infineon Technologies (63)
- Micron Technology (62)
- Freescale Semiconductor (58)
- STMicroelectronics (56)
- Texas Instruments (51)
- Philips (49)
- TECH Semiconductor (44)

Top 3 subscribing universities:

- Virginia Tech (11)
- Arizona State University (7)
- Ben Gurion Univ. of the Negev (7)

New companies and universities this month:

- Albany Nanotech
- Chunghwa Picture Tubes
- Gemalto
- Glew Engineering Consulting Inc.
- HCL Technologies
- Lilliputian Systems
- Nepes Pte. Ltd.
- RAD Technologies

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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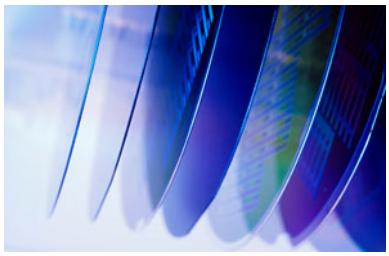
FabTime® Dispatching Module



Dispatch Configuration

Configuration projects are quoted on a fixed price basis for each site, and typically include:

- Dispatch rule and factor configuration.
- Training.
- Dispatch list feed to the MES (if applicable).

Dispatch Factors

- Batch code at the current tool.
- Lot priority.
- Downstream tool priority.
- Current tool FIFO.
- Current tool idle time.
- Downstream batch efficiency.
- Critical ratio.
- Earliest-due-date.
- Current step processing time.
- Remaining processing time.
- Current step qualified tool count.
- Up to five other site-specific factors.

Interested?

Contact FabTime for technical details.

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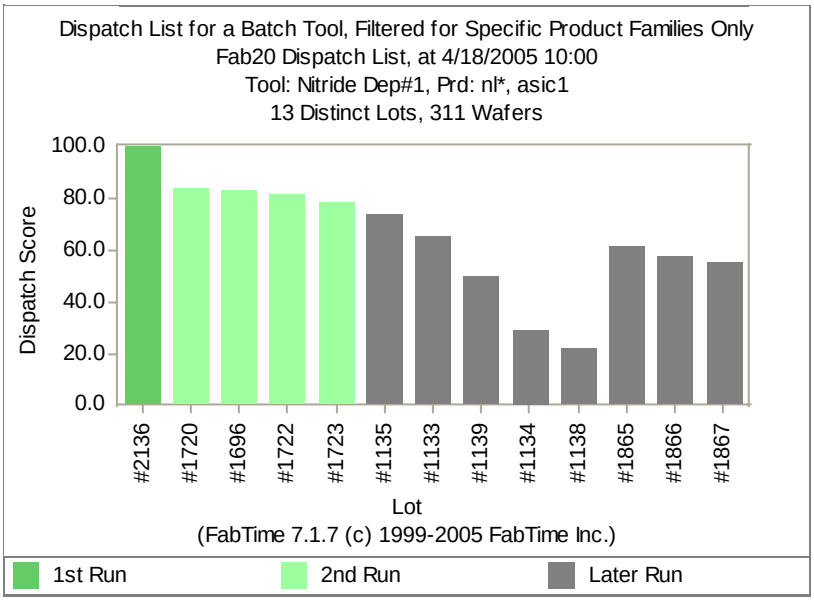
Web: www.FabTime.com

Do your operators make the best possible dispatching decisions?

- Do you struggle to balance lot priorities and due dates with tool utilization and moves goals?
- Do your critical bottleneck tools ever starve?
- Do you use standard dispatch rules, but feel that your fab's situation is more complex, requiring custom blended rules?
- Do you know how well your fab executes your strategy?

FabTime's dispatching module is an add-on to our **web-based digital dashboard software**. At any point, for any tool in your fab, FabTime will show you the list of all lots qualified to run on that tool. This list will be ordered by the dispatching logic that your site has selected for that tool. This logic can use standard dispatch rules such as Priority-FIFO and Critical Ratio. However, you can also create custom dispatching logic using any combination of dispatch factors (shown to the left).

You can display dispatch lists in FabTime, and/or export them back to your MES. FabTime also includes a dispatch reservation system to hold downstream tools when a lot is started on an upstream tool, as well as dispatch performance reporting.



FabTime Dispatching Module Benefits

- Ensure that wafers needed by management are in fact the wafers that are run, while requiring less manual intervention on the part of management.
- Improve delivery to schedule, and the display of performance to schedule.
- Document the dispatching logic used by the best operators and make this available to all shifts.