FabTime Cycle Time Management Newsletter

Volume 14, No. 5 September 2013

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 client-side support for data table sorting and searching on "view data" page and tool count trend and pareto charts; for example, to track the number of down tools at the beginning of each shift.

Editor: Jennifer Robinson

Contributors: V.A. Ames (SEMATECH Manufacturing Technology Center), John Matthews (Anadigics)

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Welcome

Welcome to Volume 14, Number 5 of the FabTime Cycle Time Management Newsletter! We're one week out from our first-ever User Group Meeting (next Wednesday and Thursday at Atmel Corporation in Colorado Springs), and we're excited about that. You can view the final agenda below. We look forward to seeing some of you there. Our software tip of the month for this issue is about using FabTime's new Tool Count trend and pareto charts to track the number of down tools by category (e.g. number of tools waiting for parts).

In our subscriber discussion forum, we have two responses to last month's article about factors that contribute to fab cycle time. That article also inspired V.A. Ames of the SEMATECH Manufacturing Technology Center to offer to write a guest article about the six sources of equipment variation and ways to control them. After noting that the number one reported impact to fab cycle time continues to be equipment downtime and availability variability, V.A. elected to share his experience and "provide some insight into what needs to be done to lessen the impact of equipment variation on cycle time." We believe that many of our subscribers will find food for thought in this article.

Thanks for reading – Jennifer

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Community News/Announcements

FabTime User Group Meeting: Final Agenda

FabTime's first-ever User Group Meeting will be held next week, September 18th and 19th, at Atmel's site in Colorado Springs, CO. Here is the final agenda for the meeting:

Day 1 Wednesday 9/18:

8:30: Welcome, introductory remarks and attendee introductions

9:00: WIP Management/Dispatch Challenge Overview

9:30: WIP Management/Dispatch Challenge

10:00: Break/Networking

10:30: Continue with Challenge

12:00: Lunch (will be provided in room)

1:00: WIP Management/Dispatch Simulation

1:30: Customer presentation #1 (Site20 Goal Automation and Alert management)

2:30: Break/Networking

3:00: FabTime recent feature additions and Roadmap

4:00: End of presentations for the day

5:00: Leave hotel for Sunset Social at North Cheyenne Cañon Mesa

Wednesday Evening Social North Cheyenne Cañon Mesa pavilion

Day 2 Thursday 9/19:

9:00 Customer Presentation #2 (Site8 Plan Earn Hours for Shift Change Tool Utilization)

10:00: Break/Networking

10:30: Customer Presentation #3 (Site29 Managing Tools belonging to Multiple Areas)

11:30: Feedback on user group meeting take-aways and site benefits "What improvements am I taking home"

12:00 Lunch (will be provided)

1:00 Optional afternoon activity: Individual FabTime Breakout sessions as needed/scheduled

1:30 Optional "Window Tour" of Atmel fab

While most attendee slots are now full, if you work at a FabTime customer site and are interested in making last-minute plans to attend, we will be happy to work with you. More details are available here.

Many thanks to Atmel Corporation for hosting this meeting! We look forward to seeing some of you there!

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

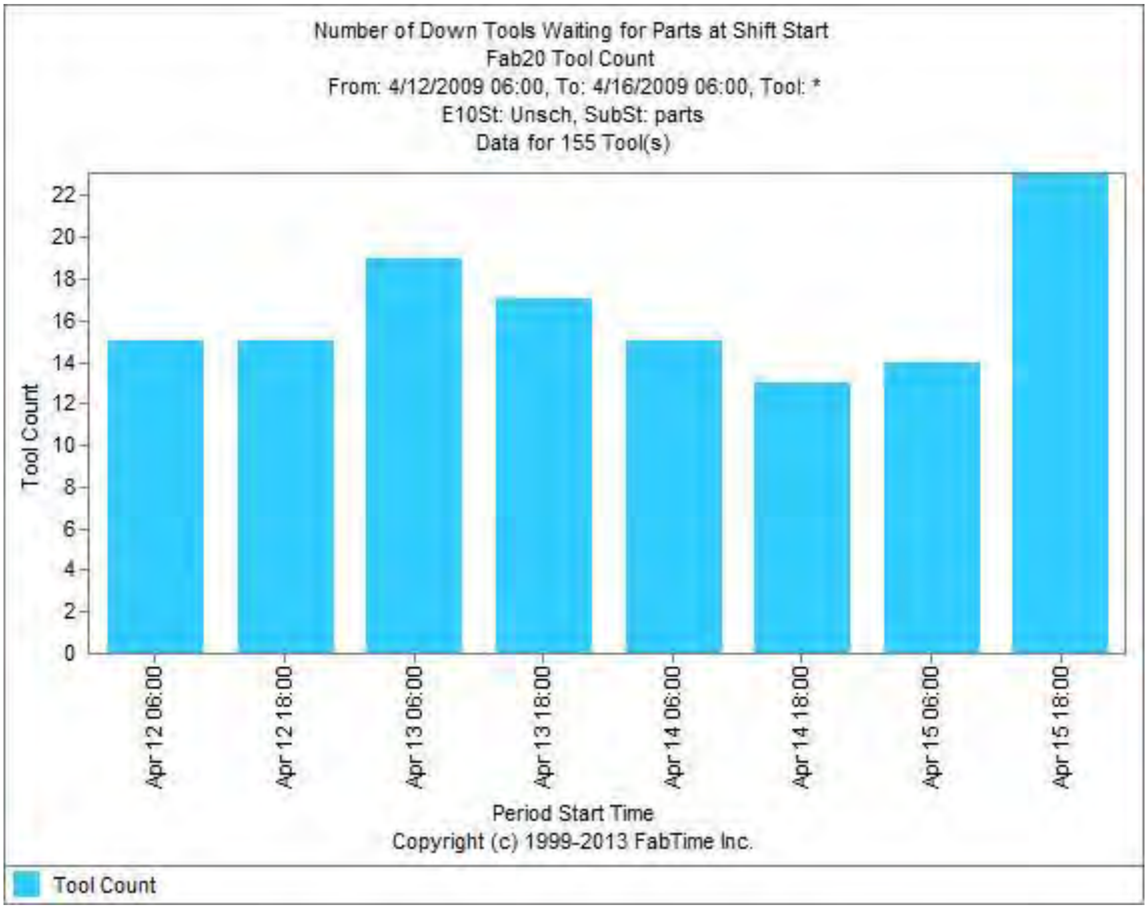
FabTime User Tip of the Month

Track the Number of Down Tools at Shift Start

FabTime's new Tool Count charts, available in trend and pareto versions, are useful for tracking things like:

1. The number of down tools at the start of each shift classified as waiting for parts;

2. The number of tools in your area that are being used by engineering, shown as a pareto by toolgroup; or



3. The number of tools at the start of each shift that are down for preventive maintenance (either trended or sliced by type of PM).

To view the first option (shown above), number of down tools waiting for parts by shift, simply:

- Show the Tool Count charts.
- Press “Go” next to “Tool Count Trend”.
- Enter “*” in the “Tool:” field, “Unsch” in the “E10St:” field, and “parts” in the “SubSt:” field. Here “parts” should be replaced by whatever code is used at your site to indicate waiting for parts. This is generally mapped to the “SubSt” (sub-state) field in FabTime. Alternatively, you can use the “Rsn” (Reason Code) field.
- Set appropriate date range and period length controls and hit enter (or press “Go”).

For the second option listed above, generate the Tool Count Pareto chart, slice by “ToolGroup”, and enter “Engin” in the “E10St:” field. Filter for your manufacturing area, as needed. For the third option, enter “Sched” in the “E10St:” field.

Naturally, any of these charts can also be filtered by manufacturing area, tool group, etc., as needed. But the general idea is to give you a quick and easy way to generate lists of different types of down tools. We hope you find these charts useful. They are available in Patch 104, released in June..

If you have any questions about this feature (or any other software-related issues), just use the Feedback form in the software. Subscribe to the separate Tip of the Month email list (with additional discussion for customers only) here. Thanks!

Subscriber Discussion Forum

Issue 14.04: Factors Contributing to High Cycle Times in Fabs

An anonymous subscriber wrote: "I read the interesting article regarding the Factors Contributing to High Cycle Times in Fabs and I have one question I would appreciate if you can answer. On the list of topics that are not part of the top 30 there are "Reentrant Flow" and "Time Constraints between Process Steps". What is the difference between the two of them and topic #10 "Queue time"? In my understanding "Queue time" and "Time constraint between process steps" are the same. Please let me know if I'm missing something."

FabTime response:

We believe that when people respond "queue time" to our survey question, they are referring in general to any time that lots spend waiting for tools to be available (whether because the tools are down or because the tools are processing other lots). This isn't really a cause of cycle time – it's more answering the question with the question. Queue time is a significant part of cycle time (queue time + process time + hold time + travel time = cycle time, with queue time usually the largest of these components). The real question is: what factors in the fab cause the queue time, because that directly contributes to high cycle times. We include this response in our list, because so many people give it, but it's more a reflection of the question not being phrased well than a true root cause.

Reentrant flow, on the other hand, refers to the fact that in most wafer fabs, lots revisit the same set of tools multiple times, for different layers. This is a structural fact about fabs, and probably IS a root cause of cycle time. If you had sufficient tools, and you could lay out the line linearly, so that no tool groups were ever revisited, dispatching would be much simplified, and your fab might be able to get better cycle times. We say "might" because you would also have an issue with smaller tool groups, and smaller tool groups tend to have higher cycle time (more queueing). Also, for most fabs, it's not cost-effective to eliminate reentrant flow – the high cost of the tools dictates that you have to share them across multiple visits. Reentrant flow contributes to cycle time via dispatch complexity and higher process time and arrival variability at the tools.

Time constraints between process steps refer to those occasional situations where you have a downstream step that must be completed within a certain window of an upstream step. Lots that exceed that window must be sent back for reprocessing (e.g. at a clean step). Queue time is a factor in tracking time constraints between process steps, but these time constraints are a special case that only occurs in certain areas of the fab. Time constraints like this contribute to higher cycle times mainly when lots exceed the time window, and get sent back for reprocessing, increasing the loading on the upstream tool (and any intermediate tools, if applicable).

John Matthews from Anadigics wrote: "I just finished reading the article on factors that contribute to high cycle time. I've been around the semiconductor industry for a long time and one thing that doesn't seem to change is the fact that fab management believes that equipment downtime is at the root of most of their problems. It has always struck me that so much focus is put on what constitutes a relatively small portion of the total time. Most tools now run in the > 90% availability range, but it is almost a knee jerk response to answer any question with "because the tool was down".

Back when I was with a previous company there were more than 100 codes to describe what was going on with a tool. About 90% of those codes were descriptors for down events and only a handful were to describe what was going on when the tool was up. And back then, the "up" states were very high level; UP, NO WIP, etc. I was involved in a great number of floor studies that showed, very clearly, that issues like "wait for operator" and "speed loss" were 2, 3, 4x the impact of downtime.

While things have gotten better, in part due to better reporting systems, I still see the same mind set in the industry today. It is still easier to justify an extra equipment/maintenance tech than it is an extra operator. But has anyone ever done the cost benefit analysis between the two? I know that the two job functions are not directly comparable. And I know that hiring an extra maintenance tech is like buying an insurance policy. However, what about hiring an extra operator for a bottleneck tool set or a tool set with high arrival rate variability? The industry frowns on operator idle time and works to increase moves/operators, while almost ignoring the impact of tool wait time on the system. I realize this is a bit of a soapbox discussion, but with downtime being #1 on the list and Operators down at #18, I couldn't help myself.

Do you know of any research or study that compares the cost benefit analysis between hiring an extra operator versus another tech?"

FabTime response:

Thanks for taking time to respond to the article. We find your comments very interesting. We do think that there's a lot going on with waiting for operators and speed losses that people in manufacturing don't necessarily look at all the time. We try to help with this in FabTime by showing the time tools spend up but waiting for operators, and including speed losses in our OEE charts. But we can't say how widely these data sources are used.

We have not seen any papers that look at operators vs. maintenance techs. A friend of ours, Bob Kotcher from Simitar Consulting, did do a paper in which he showed via simulation the benefits of "overstaffing" a photo area. The reference is:

R. C. Kotcher, "How "Overstaffing" at Bottleneck Machines Can Unleash Extra Capacity," *Proceedings of the 2001 Winter Simulation Conference*, Washington, D.C., 1163-1169, 2001. (All 1997 to 2003 WSC papers are available for free download from http://www.informs-cs.org/wscpapers.html).

Does anyone else know of literature that involves cost/benefit analysis of operators vs. technicians?

FabTime welcomes the opportunity to publish subscriber discussions and responses. Simply send your contributions to Jennifer.Robinson@FabTime.com.

Six Sources of Equipment Variation and How to Control Them

Guest Article by V.A. Ames, SEMATECH Manufacturing Technology Center

After reading the recent FabTime Newsletter article entitled "Factors Contributing to High Cycle Times in Fabs" (Vol. 14, No. 4), and seeing that the number one reported impact to fab cycle time continues to be equipment downtime and availability variability (by a wide margin), I felt that it would be useful to describe the primary sources of this equipment variability and solutions that can be implemented to control the amount of variation that occurs. I've spent the last 20 years learning about these phenomena and working with many companies and factories to address it. I want to thank FabTime for giving me the opportunity to share my experience and provide some insight into what needs to be done to lessen the impact of equipment variation on cycle time.

The first, and possibly most significant, point to consider is that variability exists in everything we do. The key to success is in determining the acceptable amount of variation for your company, setting appropriate limits, establishing controls to maintain variation within those limits, and providing methods to identify any drift so that action can be taken before those limits are exceeded (think Statistical Process Control, or SPC). Determining the acceptable amount of variation in equipment is not a simple process, however, due to the extensive number of variables interacting with each other.

While there has been intensive effort by both semiconductor manufacturers and equipment suppliers over the years to eliminate unscheduled downtime events, a much broader approach that addresses all of the sources of variation is required to be successful. In this article, we'll look at the six primary sources of equipment variability and discuss solutions that can be implemented to control the amount of variation that occurs. It's important to note that the effectiveness of these solutions will vary depending upon the age of the equipment and the level of automated data collection and analysis available.

1. Unscheduled Downtime Events

The first source of equipment variation that everyone is most familiar with is unscheduled downtime due to unexpected interruptions to production. This is, and has been, the primary focus of efforts to reduce the impact of variation on cycle time for very good reasons. When an event happens without warning, resources to address it are not always immediately available and the product may be at risk or scrapped. Early detection and warning procedures allow the equipment user to finish production or remove the product if necessary, and line up the appropriate resource on a scheduled or planned basis to repair the problem and resume production.

Although it takes time and resources, it is possible to reduce unexpected interruptions to near zero. The aerospace and airline industries are good examples showing that failures can be drastically reduced and even predicted accurately. The semiconductor industry can learn a lot from reviewing the methods used by these industries and utilizing their expertise whenever possible.

There are three important activities that must be completed to control this source of variation: 1) continuous monitoring and inspection of the equipment for any malfunctions or defects, 2) implementing corrective measures to keep defects from recurring, and 3) establishing maintenance specifications to ensure that the equipment remains defect-free. Fault Detection and Classification (FDC) is in development at many of the newer generation fabs and will be the primary approach for addressing this issue, but it is not the complete answer. More work needs to be done on identifying the most effective monitoring points, adding advanced sensors to the equipment for monitoring points that are not available, and developing models and algorithms to predict when the failures are going to occur. We also need to improve data integrity and follow-up actions by making every effort to ensure that detected faults do not occur again.

2. Scheduled Downtime

Scheduled downtime events are an unavoidable source of equipment variation. They exist in the form of preventive maintenance (PM), equipment qualifications, product setups, and corrective maintenance or changes to the equipment to prevent unexpected interruptions and failures. This can also include downtime due to equipment redesigns or material changes and software upgrades. Efforts are required to monitor parts degradation in order to effectively predict component and system failure. These efforts range from visually inspecting worn parts to developing prognostic and heath management (PHM) capability.

Equipment variation caused by scheduled downtime events can be reduced by striving to make activities effective, efficient, and consistent across all shifts and personnel. This can be accomplished through value stream mapping, 5S methodologies, effective training, and other traditional lean manufacturing practices. FabTime has also recommended that scheduled downtime events be kept as brief as possible, even if the frequency of the events is increased. The goal is to avoid long periods of scheduled downtime, which contribute directly to high cycle time.

3. Equipment Operating Parameters

Operating parameters are another source of equipment variation. Addressing this source of variation may have the greatest impact in controlling equipment availability. It is directly related to product yield and equipment availability, and has been somewhat ignored in the past. Although it is common practice to generate a tool signature on a new piece of equipment, the parameters are not always centered when new products or recipes are introduced. Frequently, the equipment is adjusted to meet process requirements instead of developing processes to meet the equipment requirements. This introduces variation into the equipment parameters which causes unexpected yield loss and future downtime.

The primary purpose of reducing the impact of operating limit variability is to generate statistically based limits across chambers and the fleet. This is needed in order to determine when anomalies occur and eliminate the need for equipment qualification time. We should only perform equipment qualifications because we are not confident that all the equipment operating parameters are within acceptable limits. Parameters for input gases, flows, temperatures, etc., need to be identified, centered to a specification, and fingerprinted. The operating parameters can then be continuously compared to the equipment fingerprint with any deviations noted and brought back to the center of the specification. Although they may both be within limits, a temperature at its upper limit and a pressure at its lower limit can cause process or equipment problems for certain products or recipes.

4. Equipment Support

Equipment support documentation and personnel skill levels can also contribute to equipment variation. It is critical to continuously increase the knowledge base. All documentation, from equipment schematics to PM procedures, should to be complete and up-to-date. This ensures that learning is captured from previous equipment repairs and that best known maintenance methods will be used to prevent future downtime events. An extensive knowledge library, with a system in place to capture new learning is essential. Expert Learning Systems and automated maintenance decision making are two activities in development.

5. Spare Parts Availability

Another source of equipment variability that is becoming a greater concern for the fabs using legacy equipment is the availability of spare parts. As equipment ages, obtaining spare parts becomes an issue because of obsolescence. The ability to have parts on hand for unexpected downtime events or even scheduled routine maintenance can greatly impact cycle time. Older (150–200 mm) fabs have put forth considerable effort to reduce this type of variation. With the onset of 450 mm, this is quickly becoming an issue in many current 300 mm equipment sets, as well.

Parts life can be extended and the alternative part qualification process greatly simplified if the first four sources of variation are reduced and under control. The OEM obsolete part notification process needs to be robust to provide an early warning to the tool owners and the most common critical parts identified so alternative solutions can be developed to aid the most users. The latest generation equipment needs to have an effective spare parts management program in place to ensure critical parts with long lead times are available on short notice.

6. Product Throughput

Even if all of the previous sources of equipment variation cited in this article are controlled at an acceptable level, there is still another variable to be considered. The product throughput rate must be optimized and meet expected production output. Handling systems may slow down over time. Cluster tool interactions may also cause multiple wafer wait times that create variations in throughput. Understanding the optimum, or theoretical, throughput rate is a key factor to addressing this source of variation. Once the theoretical throughput rate is known, it can be compared to the actual throughput rate to determine how much variation is occurring. Additional investigation then needs to be completed to find out what actions must be taken to eliminate these production time losses.

Implementation Strategy

While it is possible to reduce and control the impact of these sources of equipment variation, an implementation strategy must also be developed to continuously monitor and maintain that variability at acceptable levels. The responsibility to control equipment variation cannot lie solely with the OEM, maintenance department, equipment engineering group, or even a combination of these groups. The entire manufacturing organization, including facilities, purchasing, finance, training, and even human resources, should be part of the improvement process. A strategy must be developed and led by the executive management team to create an effective organizational structure, consisting of cross-functional teams, with a commitment to put measures in place to address all six sources of equipment variation.

Metrics must be created to identify what the acceptable level of variation is by setting appropriate goals, regularly monitoring them to determine if progress is being made, and reviewing them to see if the goals have been met. Key Performance Indicators (KPIs) for each source of variation should be developed. These may include (but are not limited to):

- number of equipment interruptions;
- ratio of repair maintenance to

corrective maintenance;

- PM completion rate and length of PM time;
- 100% first-pass equipment qualification rate;
- operating parameter excursion rate;
- skill level assessment;
- spare parts availability;
- throughput rate.

A common misconception is that this type of solution is too resource intensive and expensive to put in place. It's important to note that equipment variation reduction and control measures are not required for every tool in the fab; instead narrow the scope to bottlenecks and possible constraints consisting of critical equipment, like one-of-a-kind tools. These are the tools that impact cycle-time variability the most. Any costs associated with eliminating failures and improving equipment performance will be money well spent as equipment variation is reduced. And while some may feel in the beginning that this approach creates additional work, they will soon discover its benefits, as "fire-fighting" will become a thing of the past, and they will be able to spend time on more effective improvement activities. A culture change will indeed take place if the organization continually commits to reducing and controlling equipment variation and makes it one of its top business priorities.

Conclusion

SEMATECH's Manufacturing Technology Center recognizes that equipment variation is the top semiconductor manufacturing issue based on feedback from our member companies. We have projects in place, and new ones proposed or planned, for all six sources of equipment variation control, including the development of prognostic and health management (PHM) capabilities, fingerprinting, wait-time-waste standards, CMP pad change reduction, CVD particle control, parts obsolescence, and many more. Extensive resources have also been committed to addressing equipment variation issues through our Equipment Productivity Forums (EPFs), workshops, and beta sites. We obtain results through collaboration with the semiconductor manufacturers, OEM, alternative hardware and software suppliers, universities, and even suppliers from outside the semiconductor industries, like the aeronautical industry. If you are interested in participating and taking advantage of any of these opportunities, please contact me directly at v.a.ames@sematech.org.

In closing, I will be very surprised if the impact of equipment downtime and availability variation on cycle time drops lower in position in the FabTime poll next year, but I do hope the number of respondents making that their top selection is reduced as each of you do what you can to address all six sources of equipment variation.

Closing Questions for FabTime Subscribers (added by FabTime)

What advanced metrics do you use to monitor and improve equipment downtime and availability variability?

And for our customers, are there metrics in FabTime's software that help with this, or metrics that should be added that would provide further assistance?

Further Reading Suggestions from FabTime

J. Robinson and F. Chance, "Cycle Time Effects of Equipment Downtime," FabTime Newsletter, Vol. 4, No. 4, 2003.

J. Robinson and F. Chance, "Quantifying the Effect of Tool Downtime," FabTime Newsletter, Vol. 5, No. 7, 2004.

J. Robinson and F. Chance, "PM Scheduling and Cycle Time," FabTime Newsletter, Vol. 12, No. 4, 2011.

Subscriber List

Total number of subscribers: 2836, from 436 companies and universities.

Top 20 subscribing companies:

- Intel Corporation (148)
- Maxim Integrated Products, Inc. (137)
- International Rectifier (121)
- Micron Technology, Inc. (119)
- Fairchild Semiconductor (103)
- GLOBALFOUNDRIES (84)
- Carsem M Sdn Bhd (75)
- Texas Instruments (75)
- ON Semiconductor (69)
- X-FAB Inc. (65)
- TECH Semiconductor Singapore (58)
- Western Digital Corporation (58)
- STMicroelectronics (55)
- Analog Devices (52)
- IBM (52)
- Infineon Technologies (50)
- Freescale Semiconductor (49)
- Skyworks Solutions, Inc. (47)
- Seagate Technology (40)
- Cypress Semiconductor (33)

Top 4 subscribing universities:

- Ecole des Mines de Saint-Etienne (EMSE) (12)
- Arizona State University (8)
- Nanyang Technological University (8)
- Virginia Tech (7)

New companies and universities this month:

- Centum Rakon India Pvt. Ltd.
- SunEdison
- Xicato
- XMC Wuhan China

Sampler Set of Other Subscribing Companies and Universities:

- Clemson University (1)
- DEE - Politecnico di Bari (1)
- GAL-EL (1)
- Garmin (1)
- Georgia Tech (2)
- Headway Technologies (27)
- K.U.Leuven (1)
- Politecnico of Bari (1)
- Propsys Brightriver (1)
- Qualcomm MEMS Technologies (10)
- Salvagnini (1)
- Taylor-Deininger Partners (2)
- Technical University of Eindhoven (2)
- TOCGC (1)
- TRW (2)
- Ulvac (1)
- University of Hagen – Germany (1)
- University of Texas (4)
- University of Virginia (3)
- Vectron Frequency Devices (1)

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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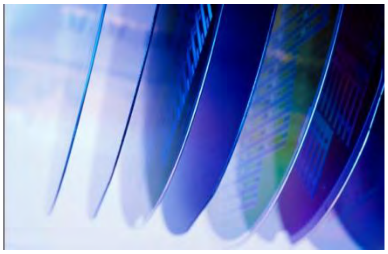
FabTime® Dispatching Module



Dispatch Configuration and Support

We offer our dispatching module for a single, fixed monthly fee (on top of your regular FabTime subscription). This includes:

- Dispatch rule configuration via user-friendly web-based interface for standard factors
- Training.
- Dispatch list feed to the MES (if applicable).
- Support and upgrades.

Custom dispatch rules and consulting from our dispatching expert available for additional fee

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
- WIP level or staging time at downstream tools.

Interested?

Contact FabTime for details.

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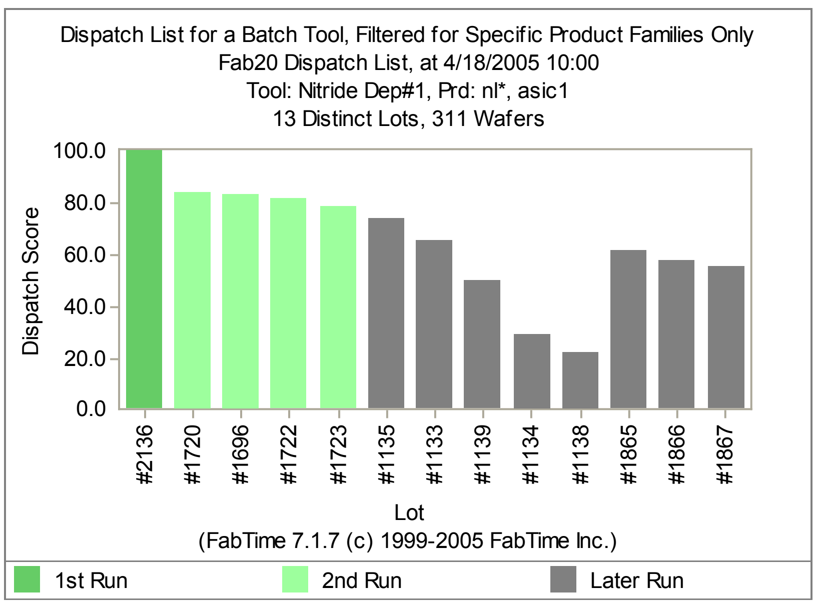
Web: www.FabTime.com

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 dispatch 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.