Use of Simulation to Improve the Kitting Process at an EMS Provider's Facility

Abhijit Joshi[1], Sachin S. Phadnis[1], K. Srihari[1], Ph.D & Ramprasad Seeniraj[2]
[1]Electronics Manufacturing Research & Services, State University of New York at Binghamton, Binghamton, NY 13902
[2]Solectron Corporation, Milpitas, CA 95035
srihari@binghamton.edu

Abstract

In an Electronics Manufacturing Service (EMS) provider's environment, smooth and continuous manufacturing flow is extremely desirable. The kitting stage is of critical importance in a streamlined Surface Mount Technology (SMT) assembly process. Based on historical data, the kitting process at the EMS provider where this research was conducted was identified as a focus for continuous improvement. This paper discusses the research undertaken to improve the kitting process at a medium volume, medium to high mix EMS provider's environment. The process improvement effort was based on a six-sigma approach with simulation being used as an analysis tool. At present, three of the five phases of the six-sigma approach have been completed with encouraging positive results.

This paper discusses problems at the kitting stage of a Printed Circuit Board (PCB) assembly process and the use of simulation to improve the process. It provides detailed information of the kitting process followed at the manufacturing facility at which this research was conducted. It was observed, from historical data, that 10% of the kits at SMT assembly setup had discrepancies. The main objective of this research was to reduce these kitting discrepancies by at least 50%. The sub-objectives were to implement a continuous flow system, improve operational performance, ensure the on-time delivery of kits, and implement a closed loop feedback system for better kitting accuracy.

The process improvement effort was based on a six-sigma approach with five phases, namely Define, Measure, Analyze, Improve, and Control (DMAIC), which ensures a steady and sustained process improvement effort. Kitting data was collected for a period of one month to define the existing problem. An extensive study was conducted in order to determine the root causes for discrepancies in the kitting process. The impact of the kitting discrepancies on machine utilization and downtime was studied. Simulation was used for the data analysis phase of the six-sigma approach. The simulation model was developed using the software package Arena 3.0, using data relevant to the kitting process. To mistake-proof the simulation model that was developed, three new sets of data, from different representative months, were collected and the output of the model was compared to these data sets. The model produced accurate results and was considered as a valid model after three extensive case studies.

1. Introduction and Objective

With the rapid growth of the electronics manufacturing sector, the pressure on the time-to-market has increased. Electronics Manufacturing Service (EMS) provider's facility utilizes a skilled workforce and serves a widely spread customer base. The suppliers of parts, materials and equipment for these facilities need to have a global presence, since the operating conditions demand a short time to delivery to the local customer as a matter of competitive necessity [1]. This imposes significant pressure on the EMS providers to assemble and ship the product within a stipulated time frame. As manufacturing lead times tend to be short, it is not desirable to have high machine downtime, high Work-In-Process (WIP), and idle man-hours.

An EMS provider always desires a smooth and continuous manufacturing flow. Kitting initiates the Printed Circuit Board (PCB) assembly process sequence. It involves gathering of parts needed for a particular assembly from the warehouse and issuing those parts to the manufacturing lineat the right time, in the right quantity. Any discrepancy in this process can directly affect the performance of the assembly line. A map of the typical kitting process at the facility in which this research was conducted is shown in Figure 1.

Kitting, or the organizing of components into logically interrelated bins prior to assembly, is an effective means for achieving air-tight inventory control and managing a critical element of the Just-In-Time (JIT) manufacturing process: the supply chain. Yet, kitting remains misunderstood and underutilized in the manufacturing process [2]

The kitting operation consists of pulling the material list at the warehouse from the Material Requirement and Planning (MRP) system, and then the kit is audited at the

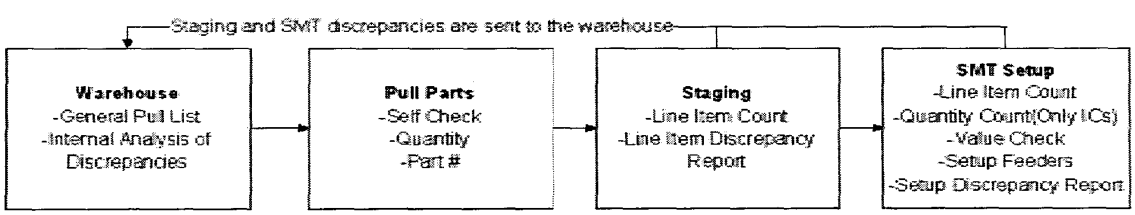

Figure 1. A Map of the Kitting Process

Authorized licensed use limited to: UNIVERSIDAD POLITECNICA DE VALENCIA. Downloaded on May 11, 2009 at 12:36 from IEEE Xplore. Restrictions apply.

warehouse itself. The completed kit is then shipped to the building, which houses the assembly line for that particular kit. At staging, the kit is audited by counting line items and then released to Surface Mount Technology (SMT) setup. If there is any discrepancy, it is notified to the person responsible for the task.

As kitting is the first operation, all other operations, directly or indirectly, depend on the scheduled kit release. As long as the kit release is on schedule and there are no discrepancies, the goal of Continuous Flow Manufacturing (CFM) can be achieved. CFM is a method of running a manufacturing facility with minimum or no buffers, resulting in least WIP. With CFM, parts arrive at each operation, just in time for processing and leave the operation just in time for processing at the next step in the assembly line. Consequently, this yields low cycle time and accurately timed shipments [3]. The adverse effects of discrepancies in the kitting process are delineated below.

- Increased machine downtime;
- Unnecessary hand loading;
- Increase in WIP;
- Customer dissatisfaction; and
- Excess manpower needs.

Some prominent kitting discrepancies are listed below.

- Under Issue of Components: In this type of error, the kit is released with unknown shortages of one or more required parts.
- Over Issue of Components: This error can be defined as the release of the kit with some components in excess of that required.
- Wrong Parts Issued: Instead of providing the right parts, sometimes a kit has parts that belong to another kit.
- Loose Parts Issued/Without Tape and Reel: Some parts need to be taped and reeled for the placement operation. It may be possible that the parts are provided loose and need to be taped and reeled prior to surface mount assembly.
- Back Order/Legal Shorts: In this case, missing or short parts are already notified to the person responsible for the kits before shipment of the kit from the warehouse to the manufacturing site.
- Missing Line Items: If a part is listed in the Bill of Materials (BoM), then it is a required line item. If the kit is released without one or more line items, this error may occur.

Any one of aforementioned discrepancies can lead to an increase in the number of set ups, machine downtime or idle man-hours, resulting in poor assembly line performance. Kitting improvement in the facility, at which this research was conducted, can be identified as a six-sigma/waste reduction project based on empirical data for a representative month. The objective of this research endeavor was to use simulation as a tool to study the kitting process and to develop a methodology to improve the same. The simulation model helped identify the errors in the kitting process and the impact of kitting discrepancies on the throughput of the manufacturing process. The simulation model was developed to compare, virtually, the flow of the kitting process at highest capacity. The model was tested and validated for 100% capacity.

This research directly assists the business objectives of the facility at which this research was performed. The major goals were as follows:

- To improve operations performance: Reducing kitting discrepancies can improve the efficiency of operations by reducing SMT downtime and cycle time, due to hand soldering of missing components.
- To implement Continuous Flow Manufacturing (CFM): Many kits are on hold at the SMT lines, waiting for discrepancy resolution. The SMT lines have to expedite non-discrepant kits that are scheduled later, to minimize the downtime that may be caused due to discrepant kits. This is in conflict with the principles of CFM.
- On time delivery: Kitting errors cause SMT downtime and the rescheduling of production runs. Minimizing the kitting discrepancies will improve production to meet on-time deliveries.
- In this research effort, two tools were primarily used. Six-sigma methodology was used as a guideline to the research and Arena simulation software was used to analyze the data. The six-sigma approach is not new to the electronics manufacturing sector. It targets 3.4 ppm defects for a particular process, which is almost a zero defect process. This approach can broadly be defined as a careful selection of the most important problems and the best personnel to work on them, with all the resources and time they need, and finding a sustainable, objective, and data driven solution [4].

In this research, a lightweight six-sigma approach was used. The research was conducted with respect to the five broad phases of the six sigma approach that are explained below.

1. Define.
   - Identify the project and the responsible personnel;
   - Define the problem, objective, goals and timeline;
   - Conduct an effort to impact analysis
   - Resource analysis; and
   - Map the process.
2. Measure.
   - Establish metrics and performance standards;
   - Develop data collection and validation plan; and
   - Use the data to establish the baseline.
3. Analyze.
   - Identify what, when, and where defects occur;
   - Establish causal relationships using data; and
   - Determine root causes using data.
4. Improve.
   - Develop Solution;
   - Asses risk of implementing the solution;
   - Demonstrate the solution; and
   - Validate primary metrics.

Authorized licensed use limited to: UNIVERSIDAD POLITECNICA DE VALENCIA. Downloaded on May 11, 2009 at 12:36 from IEEE Xplore. Restrictions apply.

5. Control.

- Develop a transfer plan;
- Establish control and actions plan; and
- Realize the benefits of implementing the solution.

In the data analysis phase, Arena, version 3.0, was used as a tool for simulating the kitting process. Simulation refers to the method and application to imitate the real system. A system can be a facility or a process. It can be real or a proposed one. With the simulation software, a replica of the real system can be developed, called as a model. Such a model is logically built with a set of appropriate assumptions, both structural and quantitative, about the system [5].

2. Methodology and Data Collection

Reducing kit discrepancies can benefit three groups significantly. They are SMT setup, staging, and the warehouse. SMT setup will spend less time in fixing kit discrepancies, which will result in a more effective production plan. The warehouse can see significant improvements in average line items pulled per day. Also, the expeditors, who resolve kit issues, can be moved to other activities, like root cause analysis and continuous improvement of the process. The following parameters can be taken into consideration for the kitting improvement project:

- Kitting defect rate;
- Machine utilization;
- SMT hand solder rates (including missing components); and
- Downtime (missing parts due to warehouse issues, misplaced/lost parts at machine).

The kitting process at the facility in which this research was conducted involves several stages starting with placing the demand in the MRP system to releasing the kit to the SMT, hand load or final mechanical assembly stage. The Program Manager (PM) carries the latest demand forecast for every project. According to that demand, daily and weekly demands are generated. This demand information is notified to the Master Production Scheduler (MPS) and the MPS is asked to generate a kit of that particular project. The MPS enters the details into the MRP system and the demand is converted into a Shop Floor Control (SFC) order. Then, it is transferred to Production Control (PC). PC checks the SFC order for each part and releases the kit if there are no shortages. If there are any shortages, the corresponding buyer is notified and the buyer contacts the vendor to purchase the necessary parts. Until then, the kit is not released to the warehouse [6].

The warehouse gets all the part numbers and the quantity required for the kit. Then, all parts are pulled manually from the bins and shipped to the manufacturing floor. For pulling the kits, the First In First Out (FIFO) system is followed. Once a kit is released to the warehouse, it is required that the kit be shipped to the manufacturing floor within 48 hours. The time required for pulling a kit depends on various factors, such as kit size, number of parts needed per assembly, manpower available, and employee skill. Typically, for large lots, more manpower is allotted and the kit is pulled at a single stretch. At the manufacturing floor, the kit is audited and if there are no discrepancies, it is released. In case of any discrepancy, the warehouse is notified and it is mandatory that the discrepancy be rectified within 24 hours [6].

To develop a simulation model for the kitting process, it is very important to identify the necessary data. Data collection is a critical activity in simulation model development. The first step in a six-sigma approach is to have baseline data in order to 'define' the problem. The simulation model, developed as a part of this research, will predict machine downtime due to material issues, increase in WIP, and delay in resolving the kit discrepancies. To define the problem, data was collected when the facility at which this research was done, was running at 100 of its % capacity. Data for a representative month was collected in order to define the problem. The following factors were considered in data collection:

- Volume of the kits that were released;
- Assembly mix;
- Number of line items per kit;
- Percentage of discrepant kits;
- Major kit discrepancies;
- Actual release date of the kit;
- Whether the kit was complete;
- Whether the kit was released incomplete;
- Overall SMT downtime; and
- Downtime due to kitting discrepancies.

According to the data collected, 19 kits had discrepancies, out of 198 released kits and the average number of discrepancies per kit was 5. The total number of kitting errors was 109. The most prominent discrepancy was back orders, with 89 occurrences. The other major discrepancy was the under issue of components, with 11 occurrences. A Pareto chart depicting discrepancies is shown in Figure 2.

In the "Measure" phase, supportive data was collected for input to the simulation model, which was used as an analysis tool. To confirm that the problem existed over a period of time, and for further analysis, a new data set was collected for two representative months. According to the data collected, there were 107 kits released for production. Out of those 107 kits, 49 kits had discrepancies due to one or more errors. The largest share of discrepancies, 44 out of 49 kits, was of back orders.

Machine downtime and idle time data was collected for a month. According to the data collected, total machine downtime was 12495 minutes (208.25 hours). Idle time due to kitting and material issues was 2180 minutes, which is 17% of the total downtime. Total production hours available for a day were 168. Average machine downtime per day was observed as 10.41 hours and out of these 17.45% occurred due to kitting errors. This suggests that the equipment was down for an average 1.817 hours due to material issues, every day. The effect of project mix and number of customers was considered in the model. There were a total

Authorized licensed use limited to: UNIVERSIDAD POLITECNICA DE VALENCIA. Downloaded on May 11, 2009 at 12:36 from IEEE Xplore. Restrictions apply.

number of 107 kits released for various projects. For the two representative months, there were four major customer accounts. More than half the kits released belonged to one project. An increase in the project mix and varying kit sizes made the process of pulling and auditing the kit more complicated. Earlier, the facility used to run large batches of PCBs with a smaller product mix. Since new customer accounts were arriving at a short notice, the kitting operation for all the projects at a single location proved difficult to manage. Often, it was observed that more than one kit per day had major discrepancies. According to data, 27 out of 66 kits of Customer A had discrepancies, and 9 out of 13 kits of Customer C had discrepancies, while 8 of 26 Customer B kits had discrepancies.

- Discrepant kits;
- Customer;
- Volume of the kit;
- Number of line items in the assembly;
- Total number of components in a particular assembly;

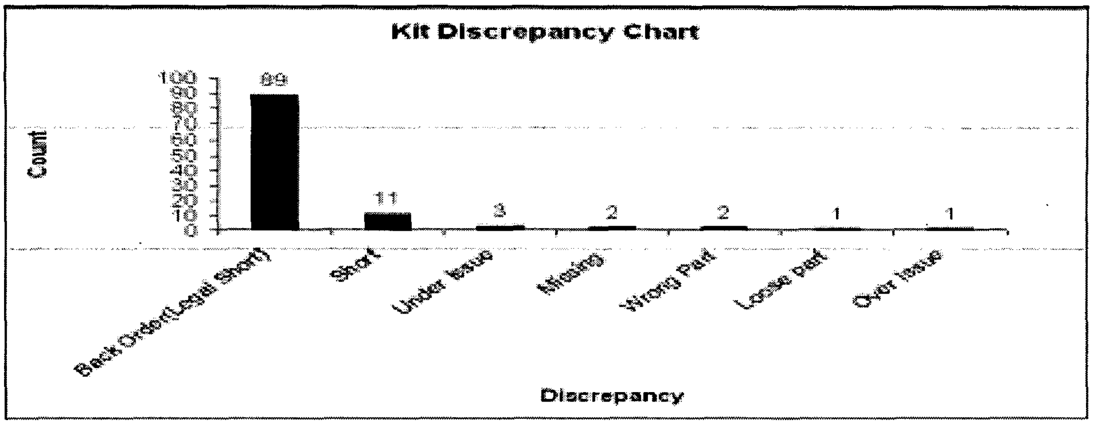

Figure 2. Discrepancy Pareto Chart

4. Simulation Model Development

The simulation model developed acts as a tool for analyzing data. The development of the model is a part of the "Analyze" phase of the six-sigma project. The model reflects the kitting process for a medium volume, low-to-high mix environment at an EMS provider.

The workstations designed in the model are:

- Warehouse;
- Staging;
- SMT;
- Hand load; and
- First mechanical assembly.

The events and attributes considered while developing the model are:

Events

- Arrival of a kit at the warehouse;
- Holding of the kits (in case of discrepancies); and
- Departure of a kit (release to SMT/FM/HL).

Attributes

- Time spent by a particular kit in the system;
- Time spent by a kit in staging, or at the warehouse;
- Machine breakdown time due to kit issues;
- Rework cost;
- Hand load time;
- Delay from vendor; and
- Time to resolve kit discrepancies.

While considering all the facts and historical data, it is necessary to provide correct inputs to the model to get a meaningful output from the simulation model. The output desired was machine downtime due to material issues, number of discrepant kits, and increase in WIP due to kitting errors. With respect to the outputs, the inputs for the model were decided. The following inputs were provided to the model:

- Interarrival time of kits;
- Kit pull time at the warehouse;
- Staging time for a kit;
- SMT process time;
- Hand load process time;
- Mechanical assembly time;
- Number of customers;
- Average kit size for a particular project; and
- Wave soldering and touch up process times.

Random number generators were used in conjunction with past data to generate inputs to the model. In order to carry out the simulation of the kitting process using random inputs such as interarrival kit times, it is necessary to specify their probability distributions. Past data sets were used to generate probability distributions for various attributes. Arena's Input Analyzer tool was used to fit the distributions.

Arena allows for the creation of a Simulate module that provides a terminating condition for the model. In this module, the length of one replication was specified as 240 hours, and the number of replications was specified as 20.

5. Case Study and Conclusions

With the simulation model developed, it was necessary to analyze the results of the model, statistically, and validate

Authorized licensed use limited to: UNIVERSIDAD POLITECNICA DE VALENCIA. Downloaded on May 11, 2009 at 12:36 from IEEE Xplore. Restrictions apply.

the model by comparing it with a new data set. It is also important to show that the model is not producing repetitive data from the past. This step is considered as a part of the "Analyze" phase of the six-sigma project. The main objective of developing a simulation model was to predict the equipment downtimes, increase in WIP, and increase in rework cost due to material and kitting issues. After the collection of supporting data for the inputs of the model, probability distributions were determined for each input. A new set of data had to be collected to compare the results of the model with the desired output.

A pilot run of the model was conducted to determine whether the model produces desired results. To smoothen out the randomness in the output, multiple replicates were run. The impact of assumptions in creating the model also had to be assessed. It was possible that the model output might not be of the same format as desired. For example, in order to calculate the rework cost, there were several other calculations, like various cost factors had to be taken into consideration. However, the final answer was based on the output from the model.

A good model should produce output that can primarily help to determine the potential increase in WIP and the increase in rework cost due to material issues. From the output, it was observed that the total flow time for a particular kit, from release to SMT completion, was 123.4 hours. The total flow time of 123.4 hours is more than specified. If there are no discrepancies and production is uninterrupted, the total flow time should not be more than 110 hours. It was also noted that the warehouse was having a large queue time of more than 48 hours. It was observed that SMT was busy for 78% of the total time. The downtime due to material issues was 22%. At SMT, no under capacity was observed because of off-loading of the assemblies to a different manufacturing facility. But, in the near future, with increasing demand, the capacity at the site itself should be increased. Moreover, there was no queue at SMT.

The warehouse was busy all the time and the average number of kits in queue was 8.563. This again can be attributed to increasing demand pattern. A priority system for kits can be maintained rigorously to avoid excessive pressure on the staging operation from the warehouse. The staging station takes more than 12 hours to process a kit. The stipulated time frame for staging a kit is 12 hours. Also, the cumulative percentage utilization for staging was found to be 99.4%. This gives a picture of insufficient capacity at the staging station. The hand load station was found to be busy most of the time and a consistent queue was formed. The average number of kits waiting at the hand load station was 5.46.

The mechanical assembly station has the most capacity available, as stations can be added for as many kits present on the floor. Since there were 5 SMT lines available, 5 mechanical assembly stations were assumed to be present. At this station, the percentage utilization was 65.74% and the queue time was found to be 2.9 hours.

Even if an accurate simulation model has been developed, the output from the model needs to be validated. Also, it was necessary to ensure that the model did not produce repetitive data from the past. Hence, to validate the model, it was necessary to collect one or more set(s) of data to compare it with the output from the model. To validate the simulation model, relevant data for a representative month was collected. The data collected was compared with the output of the simulation model. In that representative month, the number of total kits released was 93. Out of those, 38 had discrepancies. It was observed that simulation model predicted that the total number of kits was 87 for whole month. Also, at SMT, the actual downtime due to material issues was 15.98%. According to the model, the downtime was 22%. From the comparison, it was observed that the accuracy of the model is up to 85% and can be considered as valid.

After data validation, the benefits of implementing the simulation model were identified. Since the demand is increasing, the facility had to off load its SMT operation to affiliated facilities. Hence, SMT did not encounter any capacity problem. But, a queue started to form at the hand load operation since it had to operate on more kits. This led to an increase in WIP at the hand load station. Although the SMT operation is not a bottleneck at this moment, an ever-increasing demand can make it one in the near future. It might be useful if there would be more SMT lines at the facility itself. Also, at staging and at the warehouse, the queue time was found to be more than acceptable and an additional resource might prove useful. The total time required for a kit to complete mechanical assembly was longer than specified. Increase in demand may not be the only reason and research can be done to lower the flow time.

The simulation model and system is useful in predicting the percentage of discrepant kits. Furthermore, this model can act as a proactive tool to detect the errors in the kitting process. By using the model, some hidden bottlenecks were detected. Normally, the hand load station is not considered as a bottleneck operation. To cope up with increasing demand, the capacity at the SMT had already been increased. However, long queues were observed at the hand load and mechanical assembly stations. Also, it was observed that due to a high project mix, the kit auditing time has been increased. The system predicts the number of discrepant kits in a particular time period. This can lead to better scheduling of SMT assembly lines and streamlining the process. The objective of CFM can thus be achieved with the help of this simulation model. Furthermore, the long queues at the hand load and the staging stations are not due to issues that pertain to under-capacity only. It was also observed that the kitting process needs to be refined with better communication, in order to control recurring discrepancies like back orders.

Prior to developing a model, a goal was set for the improvement of the kitting process in a medium/high mix, medium volume EMS environment. Accordingly, the research was performed and the kitting process was closely observed. To reduce anomalies in the kitting process, following suggestions are put forth:

Authorized licensed use limited to: UNIVERSIDAD POLITECNICA DE VALENCIA. Downloaded on May 11, 2009 at 12:36 from IEEE Xplore. Restrictions apply.

- It was observed that even if there is a known discrepancy or a back order in the kit, the kit is released in order to follow the schedule. To follow a disciplined kitting process, no kit should be released if there is any material shortage associated with it.
- Often a kit is released to SMT by treating the discrepancy as a back order. If the kit has to be released with a back order, SMT should be aware of the shortage and scheduled beforehand for a different setup.
- All back orders should be notified to the PM and the PC when a kit is pulled from the warehouse and not after the kit arrives at the manufacturing facility.
- In case of any unforeseen kit discrepancies at the manufacturing facility, the staging supervisor must notify the PM and the PC, along with the warehouse.
- The PM and PC should be proactive in order to reduce kitting errors and have better coordination between the vendors and the customers.
- The capacity at the staging and the hand load workstations can be increased to reduce queue length.

The objective of this research was to provide the EMS provider with a sound kitting process with no discrepancies, which would help in SMT assembly process scheduling. In this research endeavor, various types of discrepancies in the kitting process were addressed in detail. Back orders were found to be the most prominent discrepancy. Factors leading to back orders were identified. After gauging the causes of discrepancies, a simulation model for the kitting process, suitable for a medium volume, medium to high mix EMS environment was developed. This generic model reflects the true kitting process at the manufacturing facility at which this research was performed. The model helps in determining the kitting process errors, potential machine downtime due to kitting issues, and increase in the WIP. Additionaly, with some enhancements in the model, the facility can predict the shipment date of a particular assembly to the customer, accurately. Furthermore, recommendations to improve the kitting process by reducing kitting discrepancies like back orders were put forth.

References

1. Meieran, E., "21st Century Semiconductor Manufacturing Capabilities", Intel Corporation Magazine, http://www.intel.com/education/, 1999.
2. Roos, G.," Buyers look to value-added services to lower cost", Purchasing Journal, Oct. 2000, Vol. 129, No. 7, pp. 36-40.
3. Dietz, K., "Fine Lines in High Yield – CFM for Better Yields", Circuitree, June 1999, pp.22-23.
4. Fuller, H. T., "Observations About The Success And Evolution Of Six Sigma At Seagate", Quality Engineering, Vol.3, No.12, 2000, pp. 24-33.
5. Kelton, D. W., Sadowski, R. P., & Sadowski, D. A., "Simulation With Arena", McGraw Hill, New York, 1998.
6. Joshi, A., "Use of Simulation to Improve the Kitting Process in an EMS Provider's Environment", Masters Thesis, State University of New York at Binghamton, Binghamton, NY 13902, 2001.

Authorized licensed use limited to: UNIVERSIDAD POLITECNICA DE VALENCIA. Downloaded on May 11, 2009 at 12:36 from IEEE Xplore. Restrictions apply.