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Nationwide Circuits

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Executive Summary:

Nationwide Circuits is a job shop that specializes in prototype engineering sampling, and low volume production. Since 1971 they have continuously remained attentive to customers needs by meeting every request of superior service and technology, through their meticulous emphasize on product quality and on-time deliveries. To achieve this quality and delivery promise, their production system utilizes enterprise resource planning (ERP) and just in time (JIT) manufacturing models to churn out high quality custom circuit boards for customers with virtually no lead time. The ERP system is used throughout the entire course of production: from the customer first placing a request for a quote on a design, through the production process, shipping the final boards, to archiving that order along with any notes. Nationwide Circuits' strives to achieve 100% quality performance through various methods of implementing continuous improvement to the manufacturing process. Their Implementation of JIT has built in quality checks at every processing station, customer follow ups and feedback, a highly active quality control department, engineers that track and correct any problems at the source, and the strict adherence to the standards set by IPC. Nationwide Circuits has been successfully implementing ERP and JIT with an incredible amount of success; a tribute to this process is the fact that they outsource circuit board manufacturing from China. Nationwide Circuits continuously seeks to attain perfection and positions themselves as "the only company capable" of producing custom circuit-boards.



Nationwide Circuits Inc.'s History & Background Information:

Since 1971, Nationwide Circuits has continuously remained attentive to customers by continually meeting every request of superior service and technology. They have always stayed committed to quality service throughout every phase of the job from design to production. Nationwide Circuits is a private company serving as a supplier to over 250 customers annually, specializing in immediate delivery of high-quality prototypes and low volume production printed circuit boards. Within the past two years, Nationwide Circuits has gone through dramatic efforts to adjust their method of production to adhere to customers' just-in-time methodology of production processes. Two years ago they were able to purchase an existing building of 24,000 ft² in Rochester, NY. In the past three months Nationwide Circuits began implementing their evolutionary ERP computer management system in efforts to achieve just-in-time production. This system remains the integral part of the company by tying together the many operational departments with continuous real-time information. There are also constant improvements being made by refining the processes, expanding capabilities, and researching the latest processes and technologies.



Mission Statement & Company Strategies:

“At Nationwide Circuits it is our goal to deliver quality printed circuit-boards on-time and to be recognized for our service.”

- Nationwide Circuits Mission Statement

Nationwide Circuits is a job shop that specializes in prototype engineering sampling with great emphasis on quality and delivery of service. Nearly all the production stations are geared by electronics with quick tooling changeovers. These highly advanced electronics provide the company the capability to manufacture single sided to complex multi-layered and flex printed circuit boards. They also work closely with customers offering technical help, input on design for manufacturability, ship-to-stock, and multiple release/JIT deliveries.

Nationwide Circuits takes tremendous pride on their ability to respond to their customers. They are able to accomplish extraordinary services through the use of in-house analytical tools such as micro-sectioning, copper thickness verification and scheduling chemical analysis, allowing consistent production of high quality products. Their staff is also well trained with use of computer integrated manufacturing to increase automation and assure the quickest turn-around time. The driving force behind this rapid and on-time production process is their enterprise resource planning software, or ERP system, which is responsible for integrating all departments and functions across the company onto a single computer system that can serve all the various departments' particular needs. This integrated computer



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based system carries all the required information of a customer's purchase order to the final steps involved in shipping and delivery of the printed circuit boards. These company strategies are used to achieve their goal of nothing less than 95% perfection in quality, delivery, and customer targeted price.

Production Process:

Customer Quote Request and Purchasing Procedures:

A customer requests a quote based on a particular design and circuit board specification. The quotes are generated based on the complexity of the design, materials needed, required tooling/setup, and manufacturing processing time. Nationwide Circuits' ERP computer program automatically calculates how many pieces fit on the panel and chooses the best panel size. Quotes are then reviewed and sent out to customers via e-mail or fax.

Once a customer has approved the quote, a purchase order number is appended to the quote. The ERP system supports yearly quantities; therefore a customer can approve a quote that requires monthly shipment of a particular board for an entire year before the purchase order requires renewal. This system also calculates how long it will take for the job to be completed and when the job must begin in order to achieve on-time delivery. Once the purchase order requirements are confirmed, the computer software generates a process traveler/job card which gives all the individuals working on the order discrete



operations that have to be completed on it, as well as the time needed for each operation.

An order confirmation is finally sent to the customer. The customer must provide a graphical representation of every layer of the circuit board (solder mask layer, silk screen nomenclature, all copper layers, the drill/route profile, and electrical information) and is also required to purchase based on the number of panels needed. The customer's circuit design also must fit on an 18x24 inch panel; otherwise the purchase order cannot be processed.

Auto CAD Process:

Once the purchase order has been completed, the software program is used to design the circuit board based on the design the customer has requested layer by layer. Each layer is designed individually which may include a copper layer, solder layer, etc. Once the design is completed, the software beings to create the panel. When creating the production panel, the program repeats the design image to fill the panel as most efficiently as possible. They then add other dimensions, nomenclature, plating bars, tooling holes, and quality control test coupons. A piece of film is then generated for every layer necessary to complete the circuit board. The number layers can vary from 1 to 26 layers, with the ability to produce different thicknesses for each layer to bring the final board thickness to the required width. Nationwide Circuits provides one design per panel and based on the price a customer can obtain multiple copies of a single design on one panel.



Imaging:

During the process of imaging, the design image is transferred from the CAD system onto film with a laser photo-plotter. This device takes the image, bitmaps it, and plots a 20x26 inch piece of film in 4 minutes. A robotic mechanism continuously loads and unloads the film one at a time. The circuit patterns are then transferred from the films onto the boards through photolithography or a stencil printed process.

All the layers that are used to build the circuit boards begin as a sheet of fiber glass with copper glued onto both sides. The object is to keep the copper that is needed and remove the unwanted copper. Photolithography is used to accomplish this. Blue photoresist, a light sensitive chemical, is applied to the panels. The panels are then run down a process line to remove any finger prints, dust, and dirt. It then goes through the cut sheet laminator where the dry film is cut off at both ends. It then takes the film that was plotted and the panel and puts it into shell-like fixture, closes it, and exposes it to ultraviolet light. Light strikes the clear areas of blue photoresist, and does not strike the dark areas of the film. The areas where the light strikes changes the photoresist to a hard polymer which sticks to the copper, while the unexposed portions remain slightly acidic. The parts that receive no light are washed away in the developer machine. The area where the light struck and the blue film is now on is the copper that we will keep for that layer. The next step involves the etching of unwanted copper.

Developer Procedure:

The panels drag through a conveyor and a sodium carbonate solution is sprayed on each panel. The film that was laminated is slightly acidic and the solution of the



detergent is slightly basic. The base reacts with the acid and removes the unwanted film. Finally it is blown dry for inspection. The panel then goes through an etcher which exposes the panel to ammoniacal etchants. This reacts to the exposed copper on the inner layers and dissolves the unwanted excess copper into the solution off the panels. The area protected by the blue film remains, leaving the desired circuit image on the panels.

Once the unwanted copper is removed, it then goes into the film stripper. Since the blue film is no longer needed the stripper removes this blue film exposing the desired copper. After the blue film is removed, the panel undergoes thorough inspection.

Panel Inspection:

The Maniabarco machine inspects the quality of each panel in 40 seconds by comparing each panel pixel by pixel to the original design image. After all the layers have been thoroughly inspected, a tooling slot punches four wholes into each panel in preparation for laminating each layer together in means of creating a single book - the circuit board.

Cobberbine Cleaning Line and Lamination Process:

The Cobberbine cleaning line prepares the surface of each panel for the application of an adhesive to glue each layer together. The machine thoroughly cleans and micro-etches the copper to provide a surface area for an adhesive to bond to. This process generally prepares the inner layers for pressing.



Starting with a heavy lamination plate, an aluminum separator plate is placed on top of the lamination plate with a copper foil face down on top of it. A sheet or more of fiber glass is then placed on the copper foil, and then placed on top of the fiber glass adhesive. Another sheet of fiber glass and copper foil facing up is placed on top of the panel with a separator plate finally placed on top. This process is repeated several times for each layer where one is glued on top of the other. Each layer is sequentially arranged in a book-like fashion with sheets of fiber glass between each layer. The fiber glass is used to laminate the panels together. The book of panels is then heated in order for the fiber glass to melt and glue the layers together with the use of a press.

The press applies an intense amount of pressure and heat onto the book of panels in order to melt the fiber glass in between each layer. The press then allows the board to cool in order for the panels to bond together. The final board has to be 12 thousands of an inch regardless of the number of layers required.

Drilling Process:

After the board has been pressed, it is drilled with several holes of various sizes. This is done through an automated machine that calculates the measurements of the board, where holes are needed, and the relative diameter of each whole. This drilling machine has interchangeable tooling abilities in which bits of different diameters can be drilled into the board during the drilling process. For quality control purposes the machine measures the tool size diameter and length every time it picks up a different tool bit. It will also test each tool bit by spinning up the tool bit to the highest speed that is required during the drilling process and examines the bit for any damages. There are



6 high speed spindles that spin up to 120,000rpm. At the base of the spindle there is a laser broken bit detector which immediately stops the drilling process when a bit is broken. Each bit varies in size to where it can even be difficult to see with the human eye, and has the life span of approximately 10 to 12 thousand drills. The average number of holes needed per board is between 350 to 500. These bits cost between \$4-8 each. There are a total of three drilling machines, each capable of processing 6 boards at once.

Electroplating:

Electroplating is generally a process in which metal is deposited on a substrate through electrochemical reactions. It is used to build up the thickness and strength of the conducting layers to provide reliable electrical conductivity between inner layers or from one side of the board to the other. It also protects the board from corrosion.

A conductive coat of palladium is put onto the board which conducts electricity through the holes that were previously drilled. They then electroplate copper into the holes to make the electrical connection between the layers. The board then goes to the film room onto the laminator to apply a plating resist onto the board. This process of coating the copper laminate with a plating resist will leave the area exposed to form the circuit pattern. The image of the external layers is applied to the resist, but this time it is a negative image. This means that the film is removed from where the image is going to be. Using the same process as before, anything not covered by the blue resist will get copper plated. They then plate additional copper along the circuit pattern, including the wholes and along the edges. Once the copper is plated fully on top of the resist,



manufacturers typically electroplate a tin or tin-lead solder on the board to protect the circuit pattern during the etching or stripping processes. An acid etch solution removes the exposed copper foil, leaving the thicker copper plating to form the circuit pattern. The unwanted layer will be stripped off the board while the tin protects the layer that needs to be preserved including the plates through the holes. The tin layer is then stripped off the board, revealing the copper circuit patterns.

Solder Coating:

Once the tin has been stripped off the board, the board runs down the same cobberbine line to clean it and give it an adhesive property. A green photo-imageable epoxy is sprayed onto the board. An image film is then used to image the board in order to harden the epoxy that needs to be kept and image off the panel that is not needed. A white photo-imageable coat is applied to the board for all the nomenclature. A solder coating is used to add solder to both sides of the board copper component before assembly. The board then goes through a tunnel oven which dries the solder mask in 3 minutes. At this point the entire board is a green color.

Ultraviolet Imaging:

A piece of image film is registered over the green panel using the holes. In the areas where light emits through the clear areas sets the mask to stay in place, the dark brown area protects the mask from ultraviolet light and then washes the mask off. The ultraviolet imager, with two 8,000 watt mercury vapor bulbs located at the top and bottom of the imager, is used to set the mask. The board then goes through the developer to remove the unwanted epoxy.



Final Cleansing Procedures:

The board finally gets cleaned, fluxed, and then is dipped into a pot of molten solder which held up between air knives which blows out the holes and shears off the excess solder off the surface. This completes the process of producing a printed circuit board.

Flying Probe Electrical Testing:

The flying probe electrical tester is a machine which consists of 4 probes, with 2 on the side. These probes move around and go end to end on all the nets to make sure that the end points are properly connected. They then probe the adjacent nets next to each other to make sure they are not connected together. This machine is capable of doing 1000 test points a minute.

Mechanical Testing:

A cross section is cut from a sample panel from each lot using a grinding process called routing where the plated holes are examined with a photomicrograph. Individual circuit boards are cut out of panels that pass quality control. Routing also tends to generate dust which may contain copper, lead, or other metals plated to the panel, which is recycled for reuse.

Electrical and mechanical tests, dimensional and visual inspections, and quality audits are performed to ensure compliance with customer requirements. Finally the finished printed circuit boards are packaged, labeled, and shipped to the customer.



Quality Control Analysis:

Nationwide Circuits' strives to achieve 100% quality performance through various methods of implementing continuous improvement to the manufacturing process, customer follow ups and feedback, a highly active quality control department, and the strict adherence to the standards set by the IPC. These methods are merely a few actions that take place to satisfy every customer.

Improvements are continuously made to the manufacturing process as more discrepancies emerge throughout the process. There is typically an engineer located at every optional department seeking to achieve high quality in a little amount of time, while limiting any problems occurring throughout the process. Every time a problem occurs within a process, the engineer examines the causes to the problem and critically analyzes the causes. Once the cause is identified a solution is made to eliminate this problem. Within the past two years, discrepancies have been found and immediately attended to in order to eliminate similar problems in the future. The company's efforts to achieve superior quality can also be seen throughout the actual production process. For example, throughout the manufacturing process of each panel, quality test stations are integrated throughout the entire process as panels are inspected at each stage of production.

The quality control department of Nationwide Circuits is primarily responsible for measuring the quality. This department seeks to locate and inform the engineers of any product defects that customers discover with their purchase. This information is



immediately related to the department engineers to locate and eliminate such defects. The quality control department is also responsible for making sure that the manufacturing production process adheres to all IPC standards. This is accomplished as continuous quality inspections are taken for every department.

Quality control measurements are also taken through customer responses and feedback. If a quote is rejected by a customer, the quality control department follows up on the customer to find out why they were unsatisfied with the quote. This information allows the company to improve areas that drive customers away from purchases. Once a customer has received their purchased product, they will typically send a report card back to Nationwide Circuits grading the quality of the purchased products. Many customers define quality through three possible measurements which include defects found in production, on-time delivery, and customer targeted price. Any percentage below 95% will receive an F as a grade. This puts the company at risk of losing a potential longer term customer.

High quality remains to be an integral aspect of the company and defines goal and mission of the company. Nationwide Circuits has been progressively successful in achieving superior quality in both service and delivery.



Scheduling & Inventory Management:

Scheduling Requirements:

Nationwide Circuits' products are made to order, and orders usually differ considerably in terms of processing requirements, materials needed, process time, and processing sequence and setups. Due to these circumstances Nationwide Circuits has implemented job-shop scheduling, providing scheduling for low-volume production with many variations in requirements. Many circuit boards vary from very simple boards, requiring less setup and tooling requirements, to fairly complex circuit designs, which require a great amount of time and setup/tooling requirements.

The processing of each job is determined by the ERP system, which automatically calculates the required time needed to complete the production of a circuit board and compares it to the date it is required to be completed. The ERP system shows what jobs are currently being done and what jobs are late or pending. A computerized station is located at each operating department, where employees can track each job throughout the production process. Many departments are also able to schedule multiple jobs simultaneously in order to reach a specific deadline. The ERP system also generates the job card which includes information on the sequence of the job process and the time it is required to arrive and complete at each department. Nearly all of the scheduling process is automatically driven by the ERP computer-based system.



Inventory Management:

To meet anticipated customer demand and smooth production requirements, the company's ERP system takes an active role in inventory management. For example, when quotes are generated, the system compares the parts that are needed against the current stock of the material or parts. The system also takes step in the ordering and re-ordering of materials or parts.

To complete ordering and re-order procedures, the program creates reports every Monday and provides information on needed supplies or material. Depending on the need, one of three people will place an order for those specific supplies and materials. Re-ordering is based on a minimum inventory quantity which varies for every material. For example, many liquid materials follow a two bin system in which a re-order occurs when the last barrel is first opened. Other supplies may need to be re-ordered weekly while others have a long shelf life. Due to the variability in order there is also variability when re-ordering supplies. Some supplies may not be used for several weeks while other supplies are used daily. Before an order is placed, the system generates the lead time for each supply and determines how much supplies can remain before a re-order is necessary. Employees are also required to mark off in inventory when a material or part is removed from the shelf. Employees are able to mark off these supplies through the use of the computer system or clip boards that are placed near material or parts storage locations. The company tries to keep an inventory quantity of 2 to 3 weeks.



Inventory storage capacity is limited to a couple 100 ft² and prevents the company from holding much inventory for customers at all. The company may hold onto overruns made during certain jobs that create excess circuit boards in case any discrepancies occur when processing a large job. Excess inventory is shelved for no more than a year.

Nationwide Circuits also goes through measures of recycling every material used throughout the production process. Liquid materials, such as tin or copper, are recycled and available for re-use. Due to strict regulations of electrical manufacturing industries, companies such as Nationwide Circuits, is required to recycle all the materials used throughout the process. Even the dust of copper material created during the routing process has to be recycled. This serves extremely advantageous when it comes to re-order these particular materials.

ERP & Just-In-Time (JIT) Production:

The ERP computer-based system serves to be the core functional element of Nationwide Circuits. The system integrates the entire customer ordering information, manufacturing, and human resources on a single computer system. However, Due to privacy security concerns, they have decided to keep financial accounting information separate from the ERP. This system has allowed Nationwide Circuits to effectively work with customers who are moving towards more of a JIT method of production. Most of the companies' customers have implemented an MRP system, which the company feels



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is not as efficient as its own ERP system; as manual adjustments are constantly being made by the companies providing those reports.

With the implementation of this ERP system, Nationwide Circuits is able to achieve JIT production where materials are moved through the production system, and services are delivered with precise timing so that they are delivered at each step of the process just as they are needed. The company is able to process low volume flexible and complex circuit patterns with little time while delivering high quality circuit boards. As the company is a ERP and JIT company, all aspects of findings described in this report relate to ERP and JIT.

Suggested Improvements:

As the whole purpose of ERP and JIT systems are for continuous improvement, their will always be suggestions on how to improve the process. One suggestion for improvement is adding an electronic ordering system, thereby completely automating the ordering process. Another suggestion for improvement would be to incorporate the accounting system into the ERP system. Both of these improvements that have been suggested have already been thought of by Nationwide Circuits however, and neither of them is being considered at this time. The online ordering system is not implemented because they like hands on personal customer communication, with hardcopies of all the quotes that they produce. Incorporating the accounting system into the ERP system has not been done as the company wants to keep its accounting records private. A



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third suggestion for improvement is to automate the ordering/re-ordering process for their raw materials. This would decrease the amount of labor they need to direct at re-ordering supplies on Monday, and leave only special needs ordering to humans. One final suggestion for improvement is to start analyzing past order data information to see if any trends appear. Although in this business it is hard to see any surface patterns, a trend might emerge doing in-depth analysis on existing data.

Project Benefits:

This project has allowed our group to experience first hand a manufacturing process using an ERP and JIT forms of production. We learned how circuit-boards are created and the technology that is used to create them. We also found out that they have to upgrade their systems every 3 to 5 years to keep up with technology – as David Ciufu put it, “what is acceptable and high quality this month, may not be next month”. Recycling is also a major part of the electronics manufacturing industry. They cannot throw anything out, and any liquids have to be purified before draining them into the sewer. David Ciufu said that the legal requirement for their industry was to have 3 copper parts per million (PPM) in the water they drain as opposed to the 5 PPM allowed in drinking water. In effect, it is illegal for them to pour a glass of drinking water down the sink. Another amazing thing that was discovered was that a lot of manufacturing firms from China outsource to Nationwide, and are still able to do it at a profit. This fact simply proves that correctly managed ERP and JIT processes can optimize businesses, even with strict regulations that companies in other countries don't have comply to.



References

“Nationwide Circuits Inc.” 30 Jan. 2003. 12 Feb. 2005. <<http://www.nciproto.com>>