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Surface Mount Technology Market Forecasting

By Dr. Shelton Houston

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Dr. Shelton L. Houston is an associate professor and associate director of the School of Engineering Technology at the University of Southern Mississippi. He also serves as the program coordinator for software engineering technology. His primary area of interest is computer hardware & software and electronics engineering technology. He is a member of ASEE, IEEE, and NAIT.

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Abstract

Most education tracts in Industrial Technology prepare students with traditional content relevant to industry. Learning these skills is critical to a student's ability to function in any industrial field and these skills have always dominated industrial education. Within recent years, however, new computer technology is rapidly changing the face of industry. This comes in many forms, one of which will be analyzed in this paper and applied to the manufacturing process in the surface mount technology market (SMT). Reliable market forecasting is essential for success in any industry. This paper presents one method of accomplishing this using artificial neural networks (ANNs) to create a forecast of the U.S. surface mount technology market. A discussion of the background and importance of SMT in the printed circuit board (PCB) manufacturing process is included, followed by a brief description of the ANN software used to produce the trends and forecasts presented in this paper. Input data are discussed along with the methodology used to generate the market predictions with appropriate schematics to illustrate the applicability and accuracy of the findings.

Introduction

As the electronics industry strives for faster, lighter and cheaper components, PCB assemblers and equipment manufacturers are required to employ the latest technological advances in order to keep up with a changing market (Frost and Sullivan, 1998). The biggest challenge that the industry faces is to meet customer demand for new device types as quickly as possible. To accomplish this effectively, PCB manufacturers have been undergoing a changeover from using through-hole technology to SMT (Association of Connecting Electronics Industries, 1998). SMT enables companies to gain the most economic advantage by improving time-to-market efficiency (Reed, 1999). Making the change from through-hole manufacturing to SMT processes is an expensive venture, requiring heavy investments. In order to justify the costly conversion to SMT, manufacturers must understand the trends and directions in the PCB and SMT market. This is especially true when considering that the PCB industry is primarily composed of small to medium-size companies that do not have large amounts of investment capital (Mussehl-Aziz, 1998).

Surface Mount Technology

The U.S. electronics industry has experienced rapid changes, particularly in the size reductions resulting from the progression from vacuum tubes to transistors and then from transistors to different types of integrated circuits (IC's). PCBs serve as the backbone of electronics; as the active elements of electronics shrink, the packaging methods change to incorporate them. Important PCB size reductions occurred when wire interconnections were replaced by components soldered in plated through-holes and again when SMT was introduced. SMT has become the industry norm for electronic assemblies and continues to grow in use with an ever-expanding electronics market. According to a report, World SMT Manufacturing Equipment (Frost and Sullivan, 1997), revenues in the worldwide SMT market are expected to grow from almost $3.3 billion in 1997 to over $8.8 billion in 2004. In fact, by most reports, SMT growth rates are very positive for the near future. Surface mounting is a newer, space-saving alternative for packaging electronic components. Unlike through-hole mounting, connecting holes in the PCB are unnecessary for SMT. Pins of surface-mounted packages are soldered directly to conductors on one side of the board, leaving the other side free for additional circuits.

Three major parts comprise a surface-mount assembly, including the surface mount component the printed circuit board and the solder joint. In SMT, the surface mount components and conductive foil traces are located on the same side of the PCB, allowing the surface mount components to be soldered directly to the circuit pads. The PCB surface may be either plastic or ceramic, and may be flexible or ridged. The major difference between conventional through-hole components and surface mount components is that the latter do not have wire leads or pins.

Cost reduction and Improved Operation achieved with SMT

Efficient use of PCB space is essential in supplying electronic end products as they become increasingly smaller (Outlook 99). Smaller surface mounted components are used to reduce the size of electronic assemblies. For most systems, the board area can be reduced by 50% for a single sided board, and by mounting components on both sides, another reduction factor of two can be achieved. Conversely, by using surface mounted components, the functional density can be doubled in the same area.

By using SMT and converting from standard logic integrated circuits to application specific integrated circuits, even reductions occur (Hutchins, 1999). System volumes are also reduced significantly, since component height is decreased. Further reduction is achieved by using fewer, denser assemblies and, correspondingly, fewer connectors and other mechanical hardware. This reduction can be another factor of 2 to 4, resulting in total volume that is approximately 20 percent of the original system. Space savings depend on the type of product and the ratio of SMT to through-hole components. In some cases, space savings of 50 to 90 percent are achieved (Williams, 1999). Additional space reductions result from mounting components on both sides of the printed board.

Improved electrical performance usually results in higher operating speed and frequency. Surface mounting components lower the parasitic lead and conductor inductance while improving capacitance, resistance and other performance characteristics. To decrease costs, skill and experience are necessary to secure packaged components at reasonable prices in a configuration that matches the assembly capability, implements and controls the process, produces optimum manufacturing time. Most vendors believe that through-hole components will be phased out in the near future. When this happens, manufacturers will have to develop the ability to design and assemble SMT products. In a 1998 survey conducted by the Association of Connecting Electronics Industries (IPC), companies were asked to indicate the percentage of PCBs containing surface mount components. The results of this survey are presented in **Figure 1**. The data reflect strong growth in the SMT market over the last 15 years. During 1999, growth is estimated to have expanded further to 92.6 percent (Association of Connecting Electronics Industries, 1998). However, the percentages are relative to the growth of the PCB market as a whole.

In order to predict the SMT market during the next few years, knowledge of past performance of the PCB industry is essential. One method of developing a forecast of future PCB industry trends is to use an artificial neural network. In this paper, an artificial neural network is used to forecast the PCB market through the year 2003. The next section describes a brief description of an ANN and how it is used to formulate future trends in the PCB market.

Neural Network Application to SMT Market Forecasting

There are many ways in which companies examine trends and directions in a market, most of which are time consuming and costly. However, employing ANNs for the task, a company can generate a highly specialized forecast in a relatively quick and inexpensive manner. ANNs are used in a wide array of applications, including financial forecasting, business decision-making, pattern recognition, behavior modeling, and medical diagnosis. It is especially useful in problems that are computationally intensive (Russel, 1996). Most ANNs, even complicated ones, are built in a matter of seconds on newer computers. It is important to note that traditional computing techniques can be used in place of ANNs to accomplish similar results, although ANNs provide an analytical alternative not limited by straight assumptions of normality, linearity, and variable independence (University of Illinois, 1999).

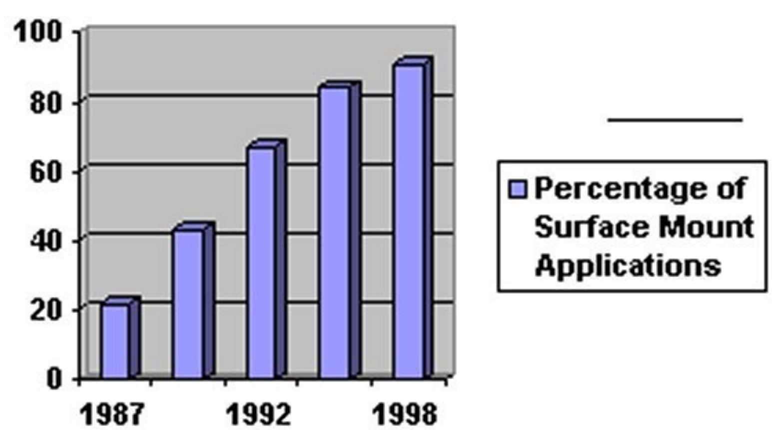
ANNs are a form of computing intelligence composed of hundreds or thousands of simulated neurons that are connected in much the same way as neurons in the human brain. Biological neurons are believed to process information in parallel, sharing a big problem coordinately. Solving problems in this way seems to be very effective, judging by the ability of the brain to recognize complex data, and to associate and apply this to new experiences (Ward Systems Group, Inc, 1996). The network "learns" patterns by continually rearranging the neurons until it achieves a test set that is similar to the real outputs in the training data. This enables the ANN to create a stable model of the behavior of the data set, such as previous annual SMT market values, and apply it to new data for forecasting purposes. Artificial Neural networks do not always use the same process to generate results and the neural network chosen often depends on the type of data being used and the desired output. For the purpose of generating the forecast in this paper, a back propagation neural network from Ward Systems Group, Inc., Neuroshell 2, was chosen. This software is currently used in design computing coursework at the University of Southern Mississippi. This system requires data entry, input and output specifications, and exercises to train the network.

Creating the Model

Data Collection Procedures

To train a network for forecasting, reliable data must be found so that a "model" of industry patterns can be

Figure 1. Percentage of PCBs using Surface Mount Components



created. To accomplish this for the SMT market, a significant amount of data influencing both the industry and the general economy were collected as input for the ANN. Various aggregate economic factors must be considered when predicting trends. Similarly, growth in the PCB shipments is based strongly on the market expansion of end products, although it is an extremely cyclical industry where long-term growth is difficult to predict (Dunn, 1998).

Since ANNs function by examining patterns to generate a prediction, the choice of input variables is critical to creating an accurate model. The variables used as the network's input dramatically affect the neural network's ability to make reliable predictions. Variable selection was based upon influence on the SMT market. **Figure 2** presents the selected variables and the correlation of their growth patterns to that of PCBs between the years 1987 –1999. **Table A** and **Table B** together are the complete set of input data used to achieve Neuroshell 2's prediction results. They have been separated for clarity and discussion. Values used for PCB-related industry data are presented in **Table A**. Aggregate economic indicators used are presented in **Table B**, along with their sources.

These data sets are combined into a single file and input to the ANN during training, each column representing one variable. Each year, or row, is a pattern in which Neuroshell 2 determines patterns and associations between the data rows and columns of variables. It is important to remember that ANNs cannot always be relied upon to produce an absolutely *correct* answer, especially if patterns are in some way incomplete or conflicting.

Using Neuroshell 2, the PCB industry was forecasted through 2003. To accomplish this, figures were generated through the desired forecast year. Using the expected growth rates for each of the industries using PCBs, data for the successive years from 2000-2003 were added to those of 87-99. The forecast years for the desired output, PCBs, were left blank. Forecasts for these years were generated by

Figure 2. Correlation in growth patterns of chosen variables to PCBs

	A	B
1	***Chosen Variables***	***Printed Circuit Boards***
2	Printed Circuit Boards	1
3	Semiconductors and Related Devices	0.930709606
4	Electronic Components and Accessories	0.933397366
5	Computer Equipment	0.970691304
6	Telecommunications Equipment	0.960695446
7	Automotive Parts and Accessories	0.896334585
8	GDP (B 1992$)	0.969153435
9	Personal Income	0.936508459
10	Manufacturing Wage Rate	0.935014925
11	Gross Private Domestic Investment(B$)	0.963427864
12	Fixed Nonresidential Investment(B$)	0.968724028
13	Personal Consumption Expenditures(B$)	0.916801802
14	Exports of Goods and Services(B$)	0.922235193
15	Industrial Production Index	0.972361202

Table A. Value of all products and services sold by establishments

Year	PCB	SEMI	ELEC	COMP	TELE	AUTO
1987	4673	19795	50258	55843	31811	92369
1988	7961	22597	56999	62773	33594	101358
1989	7354	25708	59913	59758	32754	99945
1990	7844	25977	60844	58981	36057	93020
1991	6353	29668	65233	54703	35590	90711
1992	7320	32191	73642	61969	40031	105841
1993	7378	35152	81236	64374	42190	119678
1994	8416	47265	97131	73345	49371	138982
1995	9498	65922	120129	86078	54915	147773
1996	10702	71413	127996	97592	63807	152134
1997	11986	76983	136457	106000	71585	157154
1998	13065	81140	143747	115000	79233	161869
1999	14894	86414	154162	125000	85396	166078
2000	-	96352	168037	137500	89665	170230
2001	-	107432	183160	151250	94149	174486
2002	-	119787	199644	166375	98857	178848
2003	-	133562	217612	183013	103799	183319

Millions of Dollars

PCB = Printed Circuit Boards
SEMI= Semiconductors and Related Devices
COMP= Computer Equipment
TELE= Telecommunications Equipment
AUTO= Automobile Parts and Accessories

the neural network after training the network with the known data.

Training the Network

Training the network requires continuous data processing to create a model that works very accurately on the training set. Neuroshell 2 accomplishes this by interpolating between the patterns with which it is being trained. However, a common problem experienced in using ANNs is overtraining, which occurs when the model "memorizes" patterns instead of generalizing unknown data. Choosing a point to stop training at which the network achieves the highest accuracy is critical to the ability of generating reliable forecasting results.

Figure 3 presents the actual values extracted, as well as the results of the network's prediction for years 1988, 1991, and 1996. Also included is the difference between the actual values and the network prediction. The accuracy of these results is a good indicator of how well the network has been trained. **Figure 4** includes a statistical analysis of the test set results, and serves to further strengthen the case for a very well-trained model that can be expected to generate similar accurate results for a forecast.

Results

Once the model was trained and achieved a high degree of accuracy for the test set, a production set was processed through the trained network to produce future predictions of the PCB industry itself. Neuroshell 2 could do this because it learned the "behavior" of the data set and applied known patterns and associations observed during training to the unknown PCB values between 2000-2003.

At this point, the use of the network is complete. Neuroshell 2's predictions of yearly PCB shipment values can be summarized as follows:

Year	Forecast
2000	14.8 percent
2001	8.94 percent
2002	5.74 percent
2003	3.28 percent
4 Year Avg. = 8.19 percent	

Neuroshell 2 predicts an 8.19 percent average yearly increase between 2000 and 2003. These results alone, however positive, are not enough to prove that neural networks are reliable for real-world problems. Verification of the findings of this study can only be made after future market values are known. However, other market predictions for PCBs can be examined to determine whether or not they are in line with those of the network study.

The 1999 U.S. Industry and Trade Outlook estimates that the U.S. printed circuit board market will rise at a compound annual growth rate of 8 to 9 percent through 2002. In a report on U.S. PCB market trends, the International Trade Administration found that PCBs should experience moderate expansion through 2002, growing at an estimated 8 to 11 percent annually.

Conclusions and Recommendations

The results of applying an artificial neural network to forecasting the future PCB market are that PCB demand will continue to expand over the next few years. As the PCB market grows, the use of SMT will also increase. As discussed previously, the use of SMT reduces the size of the PCBs required to produce smaller, more sophisticated electronics. Size reduction is expected to fuel expansion of PCB sales into new electronic markets in the coming years (Outlook 99).

Both the 1999 U.S. Industry and Trade Outlook and the International Trade Administration arrived at PCB

Table B. Aggregate Economic Indicators

Year	GDP (Billions of 1992$)	PERS	MWR	GPDI	FNI	PCE	EXP	IPI
1987	5649.4	3877.8	0.024	781.5	526.7	3105.3	365.6	0.932
1988	5865.2	4178.9	0.026	821.1	568.4	3356.6	446.9	0.974
1989	6062	4496.4	0.026	872.9	613.4	3596.7	509	0.991
1990	6136.3	4796.2	0.027	861.7	630.3	3831.5	557.2	0.989
1991	6079.4	4965.6	0.029	800.2	608.9	3971.2	601.6	0.97
1992	6244.4	5255.7	0.03	866.6	626.1	4209.7	636.8	1
1993	6389.5	5481	0.031	955.1	682.2	4454.7	658	1.036
1994	6610.7	5757.9	0.032	1097.1	748.6	4716.4	725.1	1.092
1995	6911.7	6072.1	0.033	1143.8	825.1	4969	818.6	1.145
1996	7164.9	6547.4	0.035	1242.7	899.4	5237.5	874.2	1.194
1997	7487.6	6951.1	0.037	1383.7	986.1	5524.4	968	1.27
1998	7809.6	7358.9	0.039	1531.2	1091.3	5848.6	966.3	1.324
1999	8120.3	7791.6	0.041	1581.7	1135	5971.4	1037.8	1.369
2000	8422.4	8214.4	0.044	1633.9	1180.4	6096.8	1114.6	1.413
2001	8687.6	8609.5	0.046	1687.8	1227.6	6224.9	1197.1	1.468
2002	8928.2	8987.1	0.048	1743.5	1276.7	6355.6	1285.7	1.523
2003	9206.1	9417.7	0.05	1801.1	1327.7	6489	1380.8	1.587

GDP= Gross Domestic Product
PERS= Personal Income
MWR= Manufacturing Wage Rate
GDPI= Gross Private Domestic Investment
FNI= Fixed Nonresidential Investment
PCE= Personal Consumption Expenditures
EXP= Exports of Goods and Services
IPI= Industrial Production Index

growth forecasts that correlate strongly with the predictions generated by Neuroshell 2, thereby lending credibility to the network's predictions. ANNs are especially suited for use in smaller companies that cannot afford to have market research conducted by an outside company, or those that are in continuous need of information from changing market areas. This paper has demonstrated that a reasonable industry projection can be created using an ANN as a forecasting method. In a rapidly changing market place, this technology has the ability to increase the speed and accuracy of a company's ability to adapt.

ANNs should therefore be considered as another tool that students should be exposed to in the course of their industrial education since forecasting is so important in the market place. For example, students could be assigned projects to determine how well certain markets follow predictable trends. As part of the project, students would have to collect data for industrial use of some component, such as the transistor, in several industrial applications over an extended period of time, preferably ten to twenty years. Using data from the first years' data, an ANN could be used to predict usage for the latter portion of the data. Comparing the predicted usage with actual values would illustrate whether the market use of that component was predictable by computational methods. Whether computer predictions were generally accurate or not, students would become familiar with the process of market forecasting and would be able to determine whether the market followed predictable trends or, for some reason, experienced unexpected anomalies. In either event, the exercise would expose students to the process of market forecasting.

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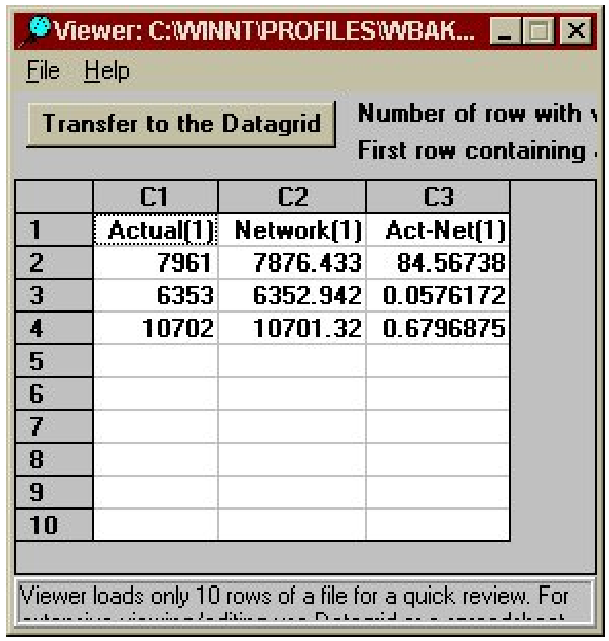
Figure 3. Training set results. Shows the difference between Neuroshell 2's prediction and actual data.



	C1	C2	C3
1	Actual(1)	Network(1)	Act-Net(1)
2	7961	7876.433	84.56738
3	6353	6352.942	0.0576172
4	10702	10701.32	0.6796875
5			
6			
7			
8			
9			
10			

Figure 4. Statistical analysis of accuracy of training results.

```
Patterns processed:      3

Output:                          C1
R squared:                       0.9993
r squared:                       0.9995
Mean squared error:              2384.036
Mean absolute error:             28.435
Min. absolute error:             0.058
Max. absolute error:             84.567
Correlation coefficient r:       0.9998
Percent within 5%:               100.000
Percent within 5% to 10%:        0
Percent within 10% to 20%:       0
Percent within 20% to 30%:       0
Percent over 30%:                0
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