

Progress in the Electronic Components Industry in Japan after World War II

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Introduction

Electronic equipment is composed of active devices (electron tubes, transistors, integrated circuits), as well as various types of components, that is, passive (resistors, capacitors, coils, transformers), functional (speakers, microphones, magnetic heads, micromotors), and electromechanical (tuners, connectors, printed circuit boards). The function of a specific piece of electronic equipment is determined by the active devices used, while components play supporting roles. This does not imply, however, that their role is unimportant; rather, performance depends heavily upon their quality and reliability. As electronic equipment gets more and more complicated, reliable components become indispensable.¹ The components industry is necessary for a sound electronics industry.

The Japanese electronic components industry has achieved a prominent position in the world market. Tables 1 and 2 show, respectively, the changes in production and export of Japanese electronic equipment, devices, and components after World War II. When the war ended, the Japanese electronic industry was said to be more than 10 years behind its Western counterparts. Twenty years later, American manufacturers were accusing the Japanese components industry of “dumping” in America. Another interpretation would be that Japanese components had become competitive in the U.S. market. Many Japanese components companies established offshore production facilities in the late 1960s, and radio components made in other Asian countries began to compete with Japanese components around that time.²

For a full understanding of the electronics industry, we need to examine not only the history of such “stars” as semiconductors and computers, but also that of electronic components. This chapter narrates the development of the electronic

TABLE I Change in Production in the Japanese Electronics Industry^a

Year	Overall	Consumer Equipment	Industrial Equipment	Electron Tubes	Semi-conductor	Electronic Components
1948	89.4	29	4	22	—	34
1949	78.6	28	5	23	—	23
1950	97.8	15	11	27	—	44
1951	183	46	38	39	—	59
1952	252	97	47	49	—	57
1953	412	184	84	79	—	64
1954	447	171	145	69	—	62
1955	539	253	119	103	—	65
1956	879	410	183	188	—	99
1957	1,349	625	286	254	39	145
1958	1,836	970	321	279	88	177
1959	3,363	1,922	413	512	190	325
1960	4,327	2,414	567	616	257	473
1961	5,089	2,898	752	502	282	655
1962	5,785	3,165	901	618	339	762
1963	5,998	3,228	1,039	569	339	823
1964	7,264	3,894	1,260	588	500	1,022
1965	7,065	3,446	1,243	494	510	1,372
1966	9,292	4,582	1,651	687	567	1,805
1967	12,288	6,156	2,360	913	738	2,121

^aValue in hundred million yen. Note one dollar was 360 yen in the period 1949–1971.

Source: *Denshikogyo Nijunenshi (Twenty Years of the Electronics Industries)*, Electronic Industries Association of Japan, 1968, pp. 2–3.

components industry in Japan up to the 1960s, with special reference to the history of improving the quality of the components. Fixed resistors are considered as an example of technological competitiveness. Some elements that influenced the development of the Japanese electronics industry are discussed.³

Japanese Electronic Components Industry till the Mid-1950s

Radio and Communications Industries before and during World War II

Radio broadcasting was initiated in Japan by a public corporation (present-day NHK) in 1925. Radio shops and importers then began to appear in cities, and domestic production of almost all kinds of radio components became well established by the middle 1930s. About one-third of the contemporary components manufacturers were founded before the end of World War II (see Fig. 1).

Electronic components manufacturers were and are principally classified into two categories: large companies that produce components as a subsidiary business,⁴ and smaller (often small-scale) companies that specialize in components manufacturing. Before the war there were several large companies with a long history of telegraph, telephone, and wireless weapons production, but they manufactured the

TABLE II Change in Export in the Japanese Electronics Industry^a

Year	Overall	Consumer Equipment	Industrial Equipment	Electron Tubes	Semi-conductor	Electronic Components
1948	0.7					
1949	0.8					
1950	2.9					
1951	4.8					
1952	5.1					
1953	6.5					
1954	4.1					
1955	19	3.4	8.6	3.3	—	3.7
1956	38	18.2	7.9	4.3	—	7.9
1957	70	41.5	7.9	5.3	0.05	15.6
1958	171	129.0	10.7	8.4	1.3	21.9
1959	488	407.1	15.0	15.4	11.9	38.6
1960	712	572.3	25.7	28.2	23.1	62.2
1961	908	684.6	49.2	36.2	33.9	104.2
1962	1,140	833.4	67.8	42.1	38.3	149.2
1963	1,378	1,017.7	86.6	49.2	40.9	171.4
1964	1,768	1,258.9	155.1	56.0	48.8	244.8
1965	2,194	1,514.2	284.6	68.8	67.1	328.1
1966	2,998	2,187.1	164.1	101.3	69.5	475.8
1967	3,622	2,669.2	340.4	71.2	55.8	485.6

^aValue in hundred million yen. Note one dollar was 360 yen in the period 1949–1971.

Source: *Denshikogyo Nijunenshi (Twenty Years of the Electronics Industries)*, Electronic Industries Association of Japan, 1968, pp. 2–3.

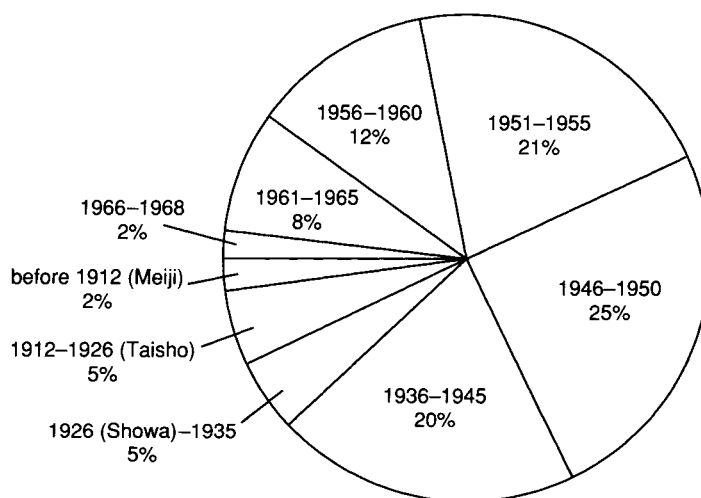


Figure 1. The years Japanese electronic components companies were founded. (Source: *Denshikogyo Sanjunenshi (Thirty Years of the Electronics Industries)*, Electronic Industries Association of Japan, 1979, p. 247)

components for their own use. At that time, components manufacture, like radio manufacture, was labor-intensive, with many kinds produced in small quantities. It was therefore not attractive to large and established companies. Some wholesalers founded subsidiary companies to manufacture radio sets and components, and a number of small manufacturers arose, often as garage factories. One important component market was amateurs, who bought them to construct radio sets. Many small companies were founded and owned by inventor-entrepreneurs who had been amateurs, so it is easy to see why this sector of the radio and components industry was amateurish in nature. It was not until 1960 that these companies began to acquire the characteristics of larger organizations.

The government discovered that radio was a useful tool for communication control. Raw materials were therefore supplied to the radio industry in spite of shortages during the war, though short-wave reception was prohibited for individuals after 1936. During the final stage of the war, all radio and components factories were converted to munitions plants, so when the war ended, the Japanese radio and components industry was virtually nonexistent.

Still, the Japanese made some original contributions to components technology in the area of research and development. In 1931, T. Takei and Y. Kato of the Tokyo Institute of Technology invented ferrite, which was utilized in magnetic cores for high-frequency coils and transformers.⁵ The Institute of Physical and Chemical Research (Riken) succeeded in mass-producing carbon film resistors in 1933. The NHK Research Laboratory (founded in 1930) started a department for radio components in 1940 and began basic research on resistors, coils, and capacitors, while stressing the improvement of electrolytic capacitors. During the war, the Japanese army and navy promoted research on radio weapons and military communications in collaboration with national and public laboratories (the Electrotechnical Laboratory, Riken, the NHK Research Laboratory, etc.) and with universities. Methods for impregnating materials for paper capacitors, ceramic dielectrics, and metalized paper were investigated. The Japanese army examined solid carbon resistors used in the equipment in the B-29 bomber. The Electrotechnical Laboratory discovered ferroelectric barium titanate in 1944.⁶ The fruits of this and other research provided the basis for the development of components technology after the war.

Postwar Reconstruction of the Japanese Radio and Components Industries

Reconstruction of the Japanese radio industry after the war was rapid because the occupation force needed to restore communications and radio in order to carry out occupation policies. People were eager to have radio sets as a medium of information and entertainment. At the end of 1945, the occupation force gave orders for the production of four million radio sets, thus inaugurating the radio boom. Since the market for industrial products had been drastically reduced, and since all munitions production was prohibited, a lot of companies began radio manufacturing, including both large and prestigious firms (not only electrical companies, but also those in other fields such as petroleum) and small new companies. In 1948, production of ra-

radio sets and the number of homes that owned them exceeded the highest prewar numbers for the first time. About eight hundred thousand sets were produced in that year. The radio boom was, at the same time, a components boom, since many radio sets were being constructed by amateurs and by semiprofessionals who bought components at stores. Components manufacturers sold their products mainly to wholesale stores because wholesalers pay cash, whereas set assemblers pay by bank draft, which could take several months to clear. The market for radio components was a seller's market. The components industry was also boosted by problems experienced by the rival finished-radio industry. Tight financial policies and the resulting depression in 1949 were difficult for the radio industry to withstand. Furthermore, the commodity tax was so heavy (around 30 percent for radio sets) that many radio set manufacturers could not survive the depression, which caused their numbers to drop from some 200 to about 20. Since retail sales of electronic components were not taxed as heavily, the boom in amateur-made radios and in components continued. It has been estimated that the number of radio sets constructed by amateurs in 1950 was three times the number made by companies.

The business upturn accompanying the Korean War (1950–1953) and the beginning of commercial broadcasting in 1952 (before then Japan had only public broadcasting, the Nippon Hoso Kyokai/NHK) accelerated the transition from cheap regenerative radio sets to superheterodyne models. In 1953, television broadcasting started, as a result of which numerous amateurs began constructing superheterodyne radio sets and television sets enthusiastically, and television components began selling very well. The quantity of components sold to wholesale stores reached a peak, with a ratio (components sold to wholesale stores/components sold to set makers) of four to one, in 1953/1954. Components manufacturers also began producing television receiver kits for amateur and semiprofessional construction, and their manufacture peaked around 1955.

Production of portable radio sets using battery-supplied miniature tubes began in 1952. These portable radios, which were the immediate predecessor of transistor radios, were produced mainly by small companies, but major appliance makers took them up within a year. Portable radio exports were considerable by 1955.

In the depression period after the Korean War, major companies such as Hitachi and Toshiba began manufacturing home electrical appliances, including radios and television sets. Most of these companies had been manufacturers of receiving tubes, and thus were creditors of the bankrupt radio set makers. When they took over the bankrupt factories, these large companies used their existing networks, which had been developed for the sales and service of motors and pumps, for the distribution and maintenance of radio and television sets. Sales of components to set manufacturers (assemblers) increased rapidly in 1955, and, as the price of manufactured sets decreased, the wave of amateur-made television sets waned. Some components makers began to assemble television and portable radio sets themselves, but failed due to undercapitalization and because they had no sales and maintenance network of their own. Thereafter the market for consumer electronics and home electrical appliances, in particular that for radio and television, has been dominated by the large companies, and components companies have confined themselves almost exclusively to electronic components.⁷

The status of components manufacturers changed substantially. Selling to large assemblers is quite different from selling to wholesalers because assemblers do not pay cash and they continuously press for price reductions and imposed acceptance tests. Many components manufacturers therefore became subcontractors for particular large assemblers.

In the beginning, the quality of Japanese components was poor, with electrolytic capacitors being especially problematic. The NHK Research Laboratory attempted to improve them, and, as a result, the Electrolytic Condenser Investigation Society was founded in 1947 by research workers of the NHK Laboratory together with engineers from the manufacturers.⁸ Superheterodyne radios demanded higher-quality components than those of regenerative receivers. A committee for the improvement of radio sets was founded in 1950 by the broadcasting corporations, the Radio Communications Industries Association (now the Electronic Industries Association of Japan), dealers, and electrical power distribution companies, all under the supervision of the occupation force. Contests for amateur-made radio sets took place. As a result, remarkable miniaturization of components for portable radios was achieved.

New components, such as tuners, deflection yoke coils, and flyback transformers, were necessary for television sets. In 1952, the NHK Research Laboratory and components manufacturers started the Television Components Investigation Society for the purpose of promoting amateur construction of television receivers. The association recommended several circuits, which were also used by many professional set makers. Television components were often copied from American designs, and by 1957, more than 57 Japanese companies had become licensees of RCA, Western Electric, EMI, and Philips. RCA's experience was especially helpful for Japanese television components manufacturers.

Quality standards for television components were higher than for radio because the number of components used in a set was several times greater.⁹ New conditions also had to be met. For example, temperatures within a vacuum tube television set often exceed 80°C or even 100°C. Furthermore, the components were subjected to very high-frequency, high-voltage, and pulsating conditions. High humidity, which is common in Japan, aggravated the situation and often led to rapid degradation in insulation. To attain uniform quality, television components manufacturers adopted mass-production systems, and incorporated acceptance tests imposed by the assemblers. Even then, some television assemblers purchased resistors made for communications (industrial) use instead of those made for consumer electronics.

Starting in 1953, radio components such as mica capacitors and variable capacitors were exported to Argentina and Brazil. This constituted the first substantial export of Japanese radio components.

Reconstruction of Communications Industry and Components Technology after the War

The occupation force pressed for the reconstruction of the communications network, with technical staff members instructing the Japanese in advanced communications technology and statistical quality control.

Government and public institutions strove to improve the quality of electronic components. A study committee on paper capacitors was founded in the Ministry of Communications in 1947, and the Electrical Communications Laboratory (ECL) (formerly a part of the Electrotechnical Laboratory, the present Laboratories of Nippon Telegraph and Telephone Corporation) began intensive research on resistors and electrolytic capacitors in 1948. Through these activities, and based upon a study carried out before and during World War II, the Paper Condenser Investigation Society was founded in 1948.¹⁰ The Ministry, recognizing that quality and reliable components were indispensable for communications equipment, and receiving the orders from the occupation force, granted the ECL the authority to determine component specifications. The Laboratory carried out sampling tests on items being manufactured and began to set standards for acceptance. The small manufacturers experienced great difficulties in meeting the requirements, so they had to learn new techniques to improve the quality. Since component prices were falling rapidly, they were highly motivated as each manufacturer wanted to secure technological advantage over its competition. The leadership of the Laboratory can therefore be considered effective, with the improvements in carbon variable resistors being one of the Laboratory's most successful contributions. This improved variable resistors technology was very useful for both communications equipment and television receivers.

Standards from America and those imposed by the Japanese government contributed much to the technological improvement: these standards came from the Japanese Industrial Standards (JIS), standards of the Japanese Self-Defense Force (founded in 1950), the American JAN (Joint Army–Navy standards), and MIL (military standards succeeding JAN). The JIS began to be promulgated in 1949, the JIS for electronic components being modeled after JAN and MIL.

After 1950, foreign technology was introduced into Japan by the Foreign Capital Law through license contracts. By 1955, Siemens had introduced techniques for manufacturing polystyrene capacitors and automatic carbon resistors.

The Ministry of International Trade and Industry (MITI) began its Grants-in-Aid Researches for Mining and Industry in 1951. Manufacturers of resistors, capacitors, transformers, and crystal resonators were supported by this system, and more than 40 projects were authorized by 1955.

Growth of Japanese Components Industry and the Foreign Market

The Turning Point

A popular expression in Japan in 1956 was “*Mohaya sengo dewa nai*” (The reconstruction period is over). Coincidentally, higher economic growth began, with the Japanese electronics and components industry also experiencing a turning point around that time. Tokyo Tsushin Kogyo (now Sony) put transistor radios on sale in 1955. Together with the portable tube-sets that immediately preceded them, they represented the first Japanese electronics goods exported in large quantities to Western markets. The emergence of transistor radios was accompanied by significant

miniaturization of components, including those suitable for printed circuit boards.¹¹ Transistor radios were the driving force of the components industry.

Around 1955 some other important transitions and new trends appeared:

1. The government began to promote the electronics industry. In 1957, "Den-shinho" (Electronics Industry Promotion Special Measures Law) was passed. This law stressed the promotion of the manufacture of components such as capacitors and resistors.¹²
2. As mentioned earlier, large companies began to dominate the consumer electronics and home electrical appliances markets.
3. Commercial technical journals specializing in electronics appeared, where previously there had been only professional newsletters and popular magazines for radio fans.¹³

Development and Growth to the 1960s

Along with the boom in home electrical appliances that began in 1953, popular demand for television receivers increased rapidly. Virtually every Japanese housewife dreamed of having a washing machine, a television set, and a refrigerator. Production of television sets in terms of value doubled each year from 1955 to 1958, and the average annual growth rate of consumer electronics from 1955 to 1960 was about 60 percent.

The components industry also grew rapidly, especially after 1957. For example, in 1955 individual factories worth hundreds of millions of yen began to be constructed. The ratio of production in 1959 to production in 1958 was 2.0 for resistors (both in terms of quantity and in terms of value), 2.0 for capacitors (in terms of value), and 2.4 for speakers (in terms of quantity).

Foreign countries, notably the United States, began to buy not only assembled radios and televisions, but also components made in Japan. Significant export of television components started around 1955. In 1958 and 1959, major American radio makers began to purchase large numbers of all kinds of components for transistor radios from Japan. They were soon followed by American components companies. The percentage of production output that went for export was, however, still not high. In 1960 it was a little under 2 percent for fixed carbon film resistors (in terms of quantity), a little over 10 percent for paper capacitors and metalized paper capacitors (in terms of quantity), 3 percent for fixed ceramic capacitors (in terms of quantity), 12 percent for electrolytic capacitors (in terms of quantity), and 20 percent for speakers (in terms of value).

Individual components manufacturers then began to study the foreign market. In 1957, an observation group of components manufacturers (consisting of 12 persons and headed by N. Matsumoto, who was the president of Pioneer Electronic) visited the United States. One of the results of the visit was the first domestic Radio and TV Parts Show in 1958 in Japan. Also in 1958, the Electronic Industries Association of Japan (EIAJ) opened an office in New York in conjunction with the Japan External

Trade Organization (JETRO). The following year, an electronic components show sponsored by the EIAJ was held in New York. Export of Japanese techniques for manufacturing components also began in 1958.¹⁴

Another milestone was the admission of the previously small-scale components companies to the Tokyo and Osaka stock exchanges in 1961.¹⁵ Admission of these companies, which had previously been ranked second or lower, to the stock market signified a remarkable elevation of power and prestige for the industry. This new status also marked the transition from founder-owned firms to public financing. Around this time there was also a serious labor shortage, so it would not be possible for components companies to remain labor-intensive much longer. Some of them constructed new factories in provinces where it was expected that an ample labor force could still be found. The industry strove to mechanize its manufacturing. Capital expenses for plant mechanization became a significant barrier to entry into the industry. Companies that secured the necessary funds in the stock market continued to grow, becoming increasingly independent of the large assembling companies. The mechanized automatic production systems were often developed by the components companies themselves, and a great many of them introduced statistical quality control and total quality control.¹⁶

Export of television components was accelerated in 1961. It is notable that Admiral and Zenith, the American protectionist leaders, changed their policy and began to purchase Japanese components in 1963. After 1964, American set makers opened buying offices in Japan, while Japanese components companies had begun establishing local offices in the United States in 1959, where they sold their components under their own brand names. After 1965, many Japanese component makers founded local production facilities in the United States. Export of components to Europe started around 1962, and the number of Japanese components technology and plants exported to Asian and South American countries increased remarkably in 1966.

National and public institutions strove to promote electronic components technology and industry. In addition to the Electrolytic Condenser Research Society and the Condenser Research Society (formerly the Paper Condenser Research Society), the Resistor Research Society was established in 1957. Today these three societies belong to the EIAJ. The introduction of the printed circuit board was motivated by the demand for highly reliable components, since replacement of defective components was difficult. In order to produce some components, however, it was still necessary to learn advanced Western technologies. From 1960 to 1970, Japanese components companies therefore entered into license contracts with American and German companies for ceramic materials, precision resistors, tantalum electrolytic capacitors, metalized paper capacitors, television tuners, transistorized tuners, and connectors.

From about 1963 to about 1965, there was a serious depression in Japan, signaling the end of the era of economic growth. Domestic sales of color television sets did not increase, and the demand for black-and-white sets had almost been satisfied. The consumer electronics and components industries were in depression, too. As a result, a business process of concentration and rationalization occurred in the components industry after 1965.

In Japan, the transistorization of radio sets was almost completed by 1964, and transistorization of television sets increased remarkably after 1965. Color television sales soared in 1966, and notable transistorization of color television sets began around 1969.

On the export scene, the shipment of tape recorders increased remarkably around 1960, and a boom of transceiver exports to the United States occurred about the same time. Exports of black-and-white television sets to the United States grew rapidly in 1962, and of large quantities of color televisions in 1964. In 1966, export of car radios to the United States increased.

In the meantime, production of industrial electronics had been growing, both in absolute terms and in relation to consumer electronics. The ratio reached a peak in 1965, when industrial electronics showed a 45 percent share of the total for production. After that, the growth of consumer electronics accelerated, though the growth rate was higher in consumer electronics. The Japanese components industry grew rapidly under these favorable conditions.

Beginning in 1967, American manufacturers charged the Japanese with “dumping” of fixed resistors and electron tubes. The following year they added transformers, speakers, tuners, capacitors, ferrites, and television sets (both black-and-white and color) to the list.¹⁷ As a consequence, the increase in export of components slowed in the early 1970s. One of the results of the American protectionist action was that Japanese electronic components manufacturers proved that they could still compete successfully because of their high-quality production.

After World War II, the inspection of many industrial products meant for export was made mandatory. The intention of this action was to eliminate the deterioration in quality of export goods resulting from the excessive competition among Japanese manufacturers. When the quality of Japanese electronic components improved substantially, the legal inspection lost its *raison d’être*. The inspections of interfrequency transformers, variable air capacitors, and composition resistors were therefore abolished in 1969, with nearly all electronic components becoming free from the inspection by 1971.

The Japanese components industry had now become number one in the world. For example, in 1970 Japan was first in the production of capacitors, the United States second: the ratio of production in Japan (in terms of quantity) vs. the United States was 10:1 for aluminum electrolytic capacitors, 4:1 for ceramic capacitors, and 4:1 for film capacitors.

Carbon Composition Resistors and Carbon Film Resistors: An Example of Technological Competitiveness

Carbon film resistors and carbon composition resistors are two major kinds of fixed resistors. Carbon composition resistors were dominant in the United States, while in Japan, carbon film resistors were used extensively. These film resistors were first developed by Germany in the 1920s and introduced into Japan in 1933, after a visit by Dr. T. Akabira of the Riken to Germany. About the time World War II ended, the Japanese “discovered” carbon composition resistors while examining communi-

cations equipment on a downed American B-29 bomber, and were surprised by their apparent “marvelous” characteristics. After the war the Japanese made painstaking efforts to produce composition resistors domestically. In the meantime, an increasing demand for precision and transistorization of electronic circuits encouraged the production of carbon film resistors, and in the 1970s, some major Japanese resistor companies stopped manufacturing composition resistors altogether. For the moment it seemed that the effort spent to learn composition resistor technology had been unnecessary, but Japanese resistor technology was improved remarkably by the attempt.

From a technological point of view, carbon composition resistors are suitable for mass-production and they are inexpensive. Their surface is intrinsically insulating, which is advantageous since a metal chassis is used for electronics circuits. Failure of carbon composition resistors is rare, but their resistance value is not precise (the values of produced carbon composition resistors have a wide range) and not stable. One can, of course, sort resistors from a large batch into groups. This is especially so for the E-series where the allowed percent deviations mean that nominal values overlap, and, theoretically speaking, the manufacturer can sell all of the products.¹⁸ In practice, however, a large number of the resistors remain unsold, because the demand is not the same in batch distribution. Furthermore, in carbon composition resistors resistance tends to change, showing large secular variation, and it alters with applied voltage, especially at high temperatures. In the humid Japanese climate, these resistors are especially problematic. In contrast, one can easily produce carbon film resistors of precise resistance, since trimming by helical cutting is possible, and the high-frequency characteristics of carbon film resistors are superior to those of the composition type. The film resistors may suffer from breakdown failures, but these failures are more probable for resistors of high resistance and small size, since the width of their film helix is narrow. The film resistors are comparatively suitable for lower resistance value, though carbon composition resistors as well as carbon film resistors of 0.5 Ω –10 M Ω can be made without much difficulty. It is also necessary to insulate carbon film resistors with a surface coating of paint.

When the war ended, a large amount of communications components produced for the Japanese army and navy were released into the market. Such resistors were available for the radio boom that occurred just after the war. As a consequence, the price of the resistors remained low, which made the manufacture of resistors unprofitable. The growth of the resistor industry was therefore retarded.

In Japan, the commercial production of carbon composition resistors began around 1951. During the Korean War, a considerable number of Japanese resistors (both carbon film and carbon composition) was exported to the United States. Rumor has it that American companies imported them in haste because of a shortage of resistors for consumer electronics equipment, major production of resistors there having shifted to military applications. Japanese composition resistors were also used for the repair of the U.S. military communication equipment during the Korean War. These sudden demands resulted in the emergence of a number of small-scale, often cottage-level resistor manufacturers in Japan. These factors hampered the rationalization of the resistor industry. Japanese engineers learned a great deal from American technology in the repair service.

At that time, the Japanese believed that carbon composition resistors were superior to the film type. It must be noted, however, that the thinking that "made in America is absolutely far superior to made in Japan" strongly influenced the Japanese engineers. They thought that imminent transition from film resistors to composition resistors was unavoidable. Film resistors were manufactured manually, and were expensive, their mean price being several times higher than that of composition resistors. The Japanese thought that home production of carbon composition resistors was without doubt necessary, and they studied them intensively.¹⁹ Efforts to improve carbon film resistors were made as well. Government and public institutions supported the efforts of industry both for film and composition resistors.²⁰ A paper by Grisdale et al. published in 1951²¹ stimulated basic research on carbon film resistors technology. Siemens's technology of precision carbon film resistors was introduced for communications use around 1954 by Fujitsu. Small-sized carbon film resistors, molded with insulating resin, were developed to compete with carbon composition resistors. Resistors of higher quality were needed for television receivers. Alkaline-free porcelain, introduced in 1953, the year of the beginning of television broadcasting, proved very effective in reducing the breakdown of carbon film resistors. For example, in the direct current field, the breakdown of resistors tended to occur because of the electrolytic corrosion of the carbon layer, which was caused by alkaline ions. New synthetic paints contributed greatly to improving the characteristics of carbon film resistors in high humidity.

The Japanese began to recognize the superior characteristics of carbon film resistors around 1955. In 1960, Riken-type RM carbon film resistors passed the MIL specification test that required operation at 70°C. In the color television boom beginning in 1966, resistors with higher precision were needed, since circuit designers wanted to use resistors with a precision of ± 5 percent. Since it was difficult to meet this requirement with carbon composition resistors, makers of color television sets had to use carbon film resistors even though they were more expensive. Resistor manufacturers thus strove to reduce the price of the film resistors by introducing mechanized helical trimming machines. As home production of the automatic machines was successfully achieved, the price of the film resistors sank below that of the composition resistors. Mechanization continued until the first half of the 1970s, by which time the size of carbon film resistors was remarkably reduced. For resistors of 1/4 W, the size of the film resistors became comparable to that of the composition type, while for smaller wattages, they had become smaller than carbon composition resistors. Film resistors of larger wattage remained considerably larger than the composition resistors, because effective surface cooling is low for larger resistors. As the transistorization proceeded, demand shifted to resistors of lower resistance and of smaller wattage, which encouraged the production of carbon film resistors.

During the 1960s the Japanese suspected that carbon film resistors would yet be superseded by carbon composition resistors, so they continued their efforts to mass-produce the composition type. A large quantity of composition resistors was exported to the United States, and the Japanese became the main supplier for the American original equipment manufacturers (OEMs). As a result, production of carbon composition resistors (in terms of quantity) in Japan in 1965 surpassed that of carbon film resistors. Figure 2 illustrates the history of carbon resistor production. In

the figure one can see that carbon composition resistors were considerably less expensive than the carbon film type around 1966. During this period, the resistor companies developed in both size and scale.

It then became apparent that carbon film resistors were superior to carbon composition resistors in both quality and in price. The following two episodes highlight the situation.

The JIS (Japanese Industrial Standards) for carbon film resistors had regulations that mandated a resistance allowance of ± 20 percent, but these regulations were dropped in the 1961 revision because they had lost their *raison d'être*, since inexpensive carbon film resistors of ± 10 percent were produced without difficulty. In contrast, the standards for carbon composition resistors of ± 20 percent tolerance were retained.

In 1961, Tama Electric—a manufacturer that held the highest position in Japanese precision resistor technology—became a licensee of International Resistance Company (IRC), a U.S. manufacturer. Tama introduced various resistor technologies, but carbon composition resistors were not among them. IRC wanted to export the composition resistor technology to Japan, but Tama did not think it necessary. Apparently, the Americans overestimated the future of the composition resistors, while the Japanese had come to realize that it was limited.

Some major Japanese resistor companies stopped manufacturing carbon composition resistors in the 1970s. As a result, the production of carbon composition resistors is now only one small aspect of the production of fixed resistors.

Elements of the Growth of the Japanese Components Industry

Here we explore some of the significant elements that influenced the successful development of the Japanese electronic components industry. First of all, the industry benefited greatly from the advanced Western technology in quality improvement.

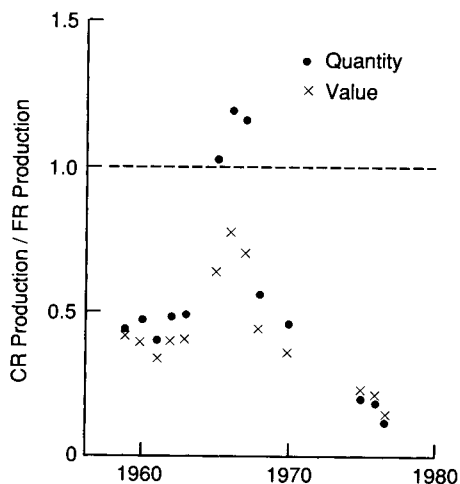


Figure 2. Change in the ratio (production of carbon composition resistors/production of carbon film resistors) in Japan. (Source: Based upon the statistics given in *Denshibuhinkogyo Kisochoosa Hokoku (Report on the Basic Inquiries of Electronic Components Industry)*, 1961 and 1964, Japan Electronics Industry Development Association; and *Denshikogyo Nenkan (Yearbook of Electronics Industries)*, for 1969, 1971–72, and 1979, compiled under the supervision of the Ministry of International Trade and Industry, Dempa Publications, Tokyo)

Japan had been dependent on European and American industrial techniques since the Meiji Restoration in 1868, and people had fallen into the habit of worshipping Western civilization. After World War II the Japanese were especially receptive to the American technology, as they thought their inferior industry and technology were the cause of their defeat. The thinking concerning the carbon resistors was a typical example. Furthermore, the Japanese were obliged by the occupation force to adopt American technology. They were therefore not only receptive, but had no other alternative. The final outcome was very favorable for the Japanese electronics industry.

During World War II, Japanese industry was isolated from Western technology. This isolation hampered Japanese technology; the Japanese had to carry out their research, development, and production during this period almost independently. However, this experience provided the basis of postwar industrial development. The lost war was, in these contexts, virtually the starting point of the successful resurgence of the Japanese electronics industry.

The growth of the components industry proceeded as consumer electronics expanded. In addition to this expanding home market, consumer equipment made in Japan found many overseas outlets. Among these products, transistor radios were a primary force for the miniaturization of components. As Japanese industry grew at a rapid rate, the shortage of labor became a serious problem. Since it was being pushed to become mechanized, the components industry could not remain labor-intensive. Manufacturers who succeeded in this miniaturization and mechanization achieved remarkable growth. One should thus not overlook the significant role played by consumer electronics, since this area is the basis of the country's electronics industry. A substantial domestic market and serious competition among domestic manufacturers were equally necessary for successful growth.

The quality of the Japanese components improved incidentally as a result of mechanization. Besides being reliable and inexpensive, components mass-produced by mechanized systems tend to be of uniform quality. Although this generalization has been true for consumer electronics components, it has not proved to be the case for industrial electronics components, since due to limited demand, they are not mass-produced by mechanized processes. Consequently, their quality is not uniform and their reliability is not necessarily high.²² Experience shows that a high rate of consumer electronics production is indispensable if one wishes to develop the technology necessary for improving quality.

Although the promotion and support of the Japanese government and other national and public institutions were important to the industry's success, it must be noted that this support was concentrated on components for communications and industrial use, not on those for consumer use. Instead, the success of components for consumer electronics must first of all be attributed to the efforts of the manufacturers themselves.

Competition between U.S. and Japanese electronics is one of the interesting issues of this industry's development. The present study sheds some light on this topic. American electronics laid stress upon the military sector and underestimated the significance of consumer electronics. The Americans seemed to ignore radio and television production while depending strongly upon Japanese suppliers for Ameri-

can OEMs. The growth of the Japanese components industry was therefore due partly, though unintentionally, to this American strategy.

Acknowledgments

In connection with this study, the author interviewed more than 30 people who are involved in the electronic components industry and related work. Thanks are due to their valuable cooperation and discussion.

Notes

1. Since the introduction of integrated circuits, the number of components used in various equipment tended to decrease. Production of components rose, however, as equipment production increased. In recent years, components have been integrated as modules and supplied to equipment assemblers. The necessity of quality components/modules has been increased.
2. Development of the Japanese electronics industry should be discussed in relation not only to the American and European ones but also to the Asian ones. For a global history, especially after the 1960s, see Gene Gregory, *Japanese Electronics Technology—Enterprise and Innovation*, 2nd ed., Chap. 30 (Chichester, England: Wiley, 1986).
3. For Western readers interested in the history of the Japanese electronics industry, the following books will be useful, though they contain little discussion of electronic components. Gregory, see note 2; Ronald Dore, *British Factory-Japanese Factory—The Origins of National Diversity in Industrial Relations* (Berkeley: Univ. California Press, 1973); Chalmers Johnson, *MITI and the Japanese Miracle—The Growth of Industrial Policy, 1925–1975* (Stanford, Calif.: Stanford Univ. Press, 1982).
4. Examples of large companies engaged in the manufacture of communications equipment: NEC, Oki, Toshiba, Japan Radio Co., and Fujitsu. Matsushita and Sharp have been the principal manufacturers of home electrical appliances and consumer electronics, with Sanyo joining them after World War II. Matsushita has also been stressing components production.
5. Ferrite was the key technology of the present TDK.
6. Ferroelectric barium titanate was utilized as material for ceramic capacitors and became the key technology of the present Murata.
7. Pioneer Electronic and Trio (now Kenwood) were exceptions: Pioneer manufactured speakers, Trio, radio coils, and they both turned themselves into hi-fi and stereo equipment makers.
8. The Electrolytic Condenser Investigation Society began issuing its organ *Electrolytic Condenser Review* in 1947.
9. For example, 10 to 20 fixed resistors and one variable resistor are used in a superheterodyne radio, while approximately one hundred fixed resistors and five or six variables exist in a black-and-white television set. A regenerative radio set requires several resistors.
10. The Paper Condenser Investigation Society has published its newsletter *Paper Condenser Review* (later *Condenser Review*) since 1948.
11. The polyethylene-insulated variable capacitors of Mitsumi Electric and the miniature intermediate-frequency transformers of Toko both contributed much to the transistor radio.

12. The MITI had identified electronics as a key sector of the industrial structure already in “Kishinho” (Machinery Industry Promotion Special Measures Law) promulgated in 1956. Kishinho, the model for Denshinho, stressed the importance of electronic components production. Carrying out the policy, MITI established the Japan Electronics Industry Development Association (JEIDA) in 1958. A yearbook of the electronics industry under the supervision of MITI appeared in 1959.
13. *Electronician* (later *Denshikogyo*), the first, appeared in 1953. Publication of *Denshigijutsu* began in 1959. *Denshi*, the newsletter of EIAJ, was started in 1961.
14. Shizuki Electric exported a plant of metalized paper capacitors to Taiwan in 1958.
15. TDK, Mitsumi, Aiwa, Tamura, Nitsuko, Trio (now Kenwood), Noble, Tokyo Cosmos, and Pioneer were all admitted.
16. The waves of mechanization and of statistical quality control came later than in the electronics equipment assembly industry. This lag can be ascribed to the much smaller size of the components manufacturers.
17. See, for example, Chapter 9 of Gregory, in note 2.
18. In the ± 20 percent series, for example, nominal resistances, such as 10 k Ω , 15 k Ω , 22 k Ω , 33 k Ω , 47 k Ω , 68 k Ω , and 100 k Ω , are chosen. The lower limit for 15-k Ω resistors is 12 k Ω , a value that is the same as the upper limit for 10-k Ω resistors. Likewise, there is no gap in the boundary between 10-k Ω resistors and 22-k Ω resistors.
19. An investigation committee on resistors in Kansai, consisting of university professors, research workers in national and public research institutes, and engineers with manufacturing companies, began the study in 1949, and published their report, “Kansai-Teikotai-Iinkai Hokoku,” in 1952.
20. A contest of resistors (carbon film and carbon composition) was organized by the MITI in 1953 in collaboration with the Electrotechnical Laboratory, the Electrical Communications Laboratory, Research Laboratory of NHK, Radio Communications Industries Association (now EIAJ), and several others.
21. R. O. Grisdale, A. C. Pfister, and W. van Roosbroeck, “Pyrolytic film resistors: Carbon and borocarbon,” *Bell Syst. Tech. J.*, Vol. 31, 1951, pp. 271–314.
22. Today it often happens that manufacturers of industrial electronics equipment use quality components made for consumer electronics instead of ordering specific industrial components.