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Embedded Systems: A study guided by patents

Sistemas embebidos: Un estudio guiado por las patentes

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Abstract

The electronic equipment industry grows an accelerated rate over years, driven mainly by the development of electronic devices intended for the comfort and convenience of the people, called embedded systems. Embedded systems are developed from a joint hardware and software is designed to perform specific tasks for which they were developed. The world market of this technology is very attractive, more demands of the industries, accelerated production and diversified. Annually, thousands of embedded

devices are launched in the market, with the most varied forms and project proposals, involving various types of electronic components, software reuse and new programming codes. In this scenario, the objective of this article is to make a study of this technology based on the amount of patent applications filed in the patent databases of the National Institute of Industrial Property (INPI) in Brazil and the World Intellectual Property Organization (WIPO).

Keywords: Embedded systems; electronic equipment; electronic components; microcontrollers; technological prospection; patents.

Resumen

La industria de equipo electrónico crece a un ritmo acelerado durante años, impulsada principalmente por el desarrollo de dispositivos electrónicos para el confort y la comodidad de la gente, llamada sistemas embebidos. Sistemas embebidos se desarrollan de una conjunto de hardware y software está diseñado para realizar tareas específicas que desarrollaron. El mercado mundial de esta tecnología es muy atractivo, más exigencias de las industrias, acelerada producción y diversificado. Anualmente, miles de dispositivos embebidos se lanzan en el mercado, con las más variadas formas y propuestas de proyectos, que implican a varios tipos de componentes electrónicos, reutilización de software y nuevos códigos de programación. En este escenario, el objetivo de este artículo es hacer un estudio de esta tecnología basada en la cantidad de solicitudes de patente presentadas en las bases de datos de patentes de la propiedad del Instituto Nacional de la Industrial (INPI) de Brasil y el mundo organización propiedad intelectual (OMPI).

Palabras clave*:* Sistemas embebidos; equipos electrónicos; componentes electrónicos; microcontroladores; prospección tecnológica; patentes.

Introduction

The world electronic components industry grows accelerated way in recent years. One of the main reasons for this growth was the emergence of electronic devices intended for the comfort and convenience of the people. These devices, called embedded systems, are present in virtually all electronic equipment moved to electricity and have the function to assist in implementing the various daily activities, though often his presence is not perceived (Cancian, Stemmer & Frolich, 2007).

The global demand of embedded systems requires this segment industries diversified production, accelerated and efficient (Reis, 2004). However, these industries face some challenges, motivated by the heterogeneous nature of the equipment and its diversification. The main challenges faced by the same are: the high costs of production

of the equipment, the time spent in the development of embedded applications and the difficulties encountered in the preparation and implementation of projects (Turley, 2003).

Despite these challenges, the electronic components industries are responsible for the production and marketing of billions of microprocessors used in developing embedded systems. Approximately 99% of the microprocessors produced by these industries are intended for these devices (Reis, 2004).

Over the years, thousands of embedded devices are launched in the market, with the most varied forms and project proposals, involving various types of electronic components, software reuse and new programming codes. However, the development of these devices has become quite complex, reaching high levels of integration between the hardware and the software of embedded application (Taurion, 2005).

In an embedded system design, hardware and software components must be well aligned and integrated, in order to meet all the demands and requirements of this market. It is worth mentioning that the development projects of the equipment always work on preparation of a new hardware or customization of an existing one (Lee, 2002).

Given this context and the relevance of this technology to the world of electronic equipment market, this work aims to do a prospective study based on the number of patents filed in patent databases of Brazil (INPI) and the World Intellectual Property Organization (WIPO).

Theoretical Review

The term embedded system first emerged in 60's. The first application to use this terminology was an electronic device developed at the Massachusetts Institute of Technology (MIT) in the United States, by Charles Stark Draper, called the Apollo Guidance Computer (AGC). The AGC was a computer that had the function of providing computational resources for aircraft Apollo, assisting in your control, guidance and navigation (Jiménez, Palomera & Couvertier, 2014).

In the Decade of 60, the programming language used in the development of embedded applications was the Assembler, because it is a specific language for programming in microprocessors and microcontrollers. From the years 70, other programming languages were introduced on the stage of development of these applications, among which we can highlight the language "C" (Ball, 2002).

At that time, the Assembler languages and C were used with the goal of trying to reduce to the maximum the amount of codes used in the development of an application loaded, since the electronic components of hardware used on these devices had too many restrictions, such as: processing, memory capacity and power consumption. It is worth noting that these languages were difficult to be programmed and not allow the reuse of

code from other projects, making the development of an application shipped as single (Barr, 2009).

With the emergence of high-level languages, the problems related to code reuse, were minimized. These languages, in addition to bringing more security to the embedded applications, allowed still the reuse of code belonging to other projects, making this way more agile development (Corsaro, 2003).

One of the high-level languages that have been excelling in the scenario of development of embedded applications is JAVA (Java Virtual Machine - JVM). JAVA has brought to this market more agility and speed, in addition to meeting the complex levels of systems requirements specified by these applications (Wehrmeister, 2008).

Embedded systems are computer systems formed from the combination of hardware (electronic components) with software (firmware) (Ball, 2002). São constituídos de sistemas específicos que reúnem a capacidade computacional, a independência de operação e os modos próprios de funcionamento dos dispositivos e aplicações embarcadas (Heath, 2003).

Its architecture consists of a processing unit that is attached to a printed circuit board. In addition, the embedded systems can be divided into three parts: the hardware (physical), the operating system (optional) and application software (firmware or embedded software) (Ball, 2002).

The hardware that makes up an embedded system is basically composed by a CPU, memory, and peripherals. The main types of processors used in embedded systems projects are: microcontrollers, microprocessors and digital signal processors (DSPs) (Barr, 1999). But, depending on the application, we can still find other types of processors: ARM, MIPS, Coldfire/68 k, PowerPC, x 86, PIC, 8051, Atmel AVR, Renesas H8, SH, V850, M32R, FR-V, Z80, Z8 and ASIPs (Application Specific Instruction Set Processor).

The microcontrollers used in manufacturing of embedded systems are of particular use and usually have: a central processing unit (CPU), ROM and Flash memories, in addition to other peripherals integrated into the CHIP. The CPU of these microcontrollers is responsible for processing signals, while the ROM and Flash are responsible respectively for operating system and application software (firmware) (Wolf, 2012).

Already the microprocessors used in these devices have serious limitations of hardware, such as memory and processing. For this reason, one of the main concerns in the development of embedded applications is with the optimization of hardware

resources. Its main function is to control one or more functions of the device (Heath, 2003).

Embedded operating systems (SOE) are small and carry out a limited amount of instructions. Its use is not mandatory in all applications, only those that have a high degree of complexity and that must make the application access management or hardware. The SOE has the function of providing communication services and escalation processes, in addition to performing all your instructions in the application itself (Carro & Wagner, 2003).

Application software (firmware) is composed of several distributed between the various processes involved in the application processors, making communication between the various hardware interfaces. All embedded devices have specific inbound and outbound interfaces. These interfaces are designed to support a particular application and perform specific tasks for which they have been programmed (Ball, 2002).

In a project of development of embedded systems, the firmware is responsible for most of the time and costs spent on the project, in view of their complexity, flexibility and changes throughout the project (Nebel, Oppenheimer, Schumacher, Kabous, Radetski & Putzke-Röming, 2001).

The popularization of microprocessors made embedded systems are increasingly present in our daily life, and can be found in various electronic equipment around the world, such as: DVD-players, televisions, toys, washing machines, telephones, stereos, watches, cell phones, microwave ovens, bank cards and etc. (Klaus, 2003).

Market research conducted by IDC (International Data Corporation), published in 2011 in Computerworld Magazine, showed that the world market for embedded systems is in full growth. The main reason for this scenario was the creation of embedded applications more complex and sophisticated, containing the most modern operating systems, connectivity to the cloud (Internet) and faster processors. According to IDC, in 2011, were sold in the world more than 1.8 billion embedded systems, which correspond to approximately 19% of all worldwide electronics sales, representing revenue of nearly $ 1 trillion dollars to manufacturers of electronic components (IDC, 2011).

In 2013, the embedded systems market was estimated at approximately $ 142.8 billion, showing an annual growth rate of 6.3%, and embedded hardware responsible for 93.8% of this total (GVR, 2014).

To keep up with all this growth, electronic components manufacturers need to invest more and more in new technologies, able to meet all the market demand and the complexity required in the development of new embedded applications. In a highly

competitive and globalized market, how is this market it is essential to have speeded and efficiency in the development, production and marketing of new products.

Methodology

The methodology used in this research told initially with a bibliographic survey conducted in several databases of scientific papers on the technology of embedded systems.

Then, a technological prospecting was carried out on the basis of the patent applications of this technology, deposited in the patent databases of the National Institute of Industrial property (INPI) in Brazil and the World Intellectual Property Organization (WIPO).

The technological prospecting was carried out in September 2016 and used as search strategy inserting keywords in Portuguese and English, in the fields related to "Title" and "Summary" of the bases mentioned above.

The keywords used in the search were: Embedded system, “Embedded system”, Embedded devices, “Embedded devices”, Sistemas embarcados (in Portuguese), “Sistemas embarcados” (in Portuguese), Dispositivos embarcados (in Portuguese) and “Dispositivos embarcados” (in Portuguese).

The use of quotation marks ("") in some keywords aimed to delimit the search universe, since their use returns results more specific, with a high degree of accuracy. The quotes are widely used in searches involving phrases or compound words, as is the case of this research. Without the uses of the same results are very comprehensive, not reflecting the reality of that if you want to find in the search.

Finally, all data collected in the survey were transferred to a spreadsheet, where later were selected, analyzed and tabulated, according to the following categories: annual evolution of patents deposited, countries of origin, international patent classification code (IPC), technology holders and profile of depositors.

Results and Discussion

For the study of this technology were carried out research in two databases of patents. A national database, the INPI, that is responsible for registering and granting of patents in Brazil and other world database, the PatentScope of the World Intellectual Property Organization (WIPO).

The WIPO database, PatentScope, was chosen because it is a base that provides free access to over 58 million documents of patents in the world. The WIPO is headquartered in Geneva, Switzerland and was established in 1967, with the aim of

encouraging the development of intellectual creation activities and promote the protection of intellectual property worldwide. Currently, the WIPO has 189 Member States and manages 26 international treaties, including the Patent Cooperation Treaty (PCT), covering 151 countries.

According to the results obtained through the searches in the databases of the INPI and WIPO in relation to the technology of embedded systems, we can observe the following scenario (Table 1):

Table 1- Total deposits of patent searched in INPI databases and WIPO.

Keywords	INPI	WIPO
Embedded system	-	46.505
"Embedded system"	-	3.308
Embedded devices	-	64.896
"Embedded devices"	-	1.559
Sistemas embarcados (in portuguese)	11.026	-
"Sistemas embarcados" (in portuguese)	196	-
Dispositivos embarcados (in portuguese)	12.250	-
"Dispositivos embarcados" (in portuguese)	62	-

Source: Data collected in the databases of the INPI and WIPO (2016).

For searches conducted in abovementioned databases were used two forms of queries. At first, the keywords searched were inserted in the fields pertaining to the "Title" and/or "Summary" without the demarcation of quotation marks (""). In the second, the same keywords were entered in the same fields but with the delimitation of the quotation marks (""). It was observed that the first form of query results were very extensive, bringing data that were not directly related to the purpose of the research. The second form of consultation was considered the most suitable for the research the results obtained have brought specific data with respect to technology research. Thus, the development of this research will be based on the analysis of the data obtained from the second query form (Table 2).

Table 2- Total of patent documents analyzed in this research.

Keywords	INPI	WIPO
"Embedded system"	-	3.308
"Embedded devices"	-	1.559
"Sistemas embarcados" (in portuguese)	196	-
"Dispositivos embarcados" (in portuguese)	62	-
Total	**258**	**4.867**

Source: Data collected in the databases of the INPI and WIPO (2016).

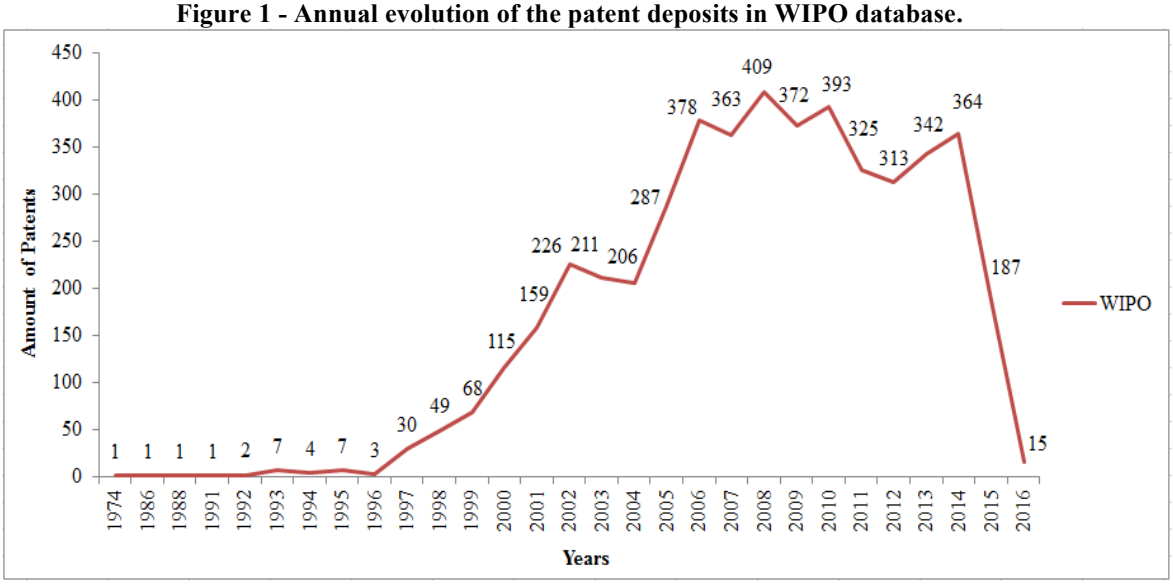
With respect to the bases searched the database of WIPO was the one that presented the greatest amount of deposit of patents related to the technology of embedded systems, with 4,867 deposits. Already in the INPI database were found only 258 patent documents related to this technology.

Figure 1 shows a quantitative overview of patent applications deposited in databases of WIPO for the period 1974 to 2016.

The beginning of the patent records of embedded systems, according to the data collected, emerged in the mid-70, more precisely in 1974. It was a Russian patent application entitled, *"Multichannel Transmitting Active Phased Array Monitoring Device"*, required by Gosudarstvennoe predprijatie "Nauchno-issledovatel ' skij institut" Kvant ", which was intended to improve the accuracy of tracking on radar system".

In 1986, after a long period without patent deposits of embedded systems in WIPO, was registered by the company Hewlett-Packard Company (HP) the second filing patents related to this technology. The request was made for a patent of invention titled, *"Method and Apparatus for Preventing Performance of Critical Operation Unless Selected Control Conditions are Satisfied"*, which was intended to prevent the performance of a critical operation.

Figure 1 - Annual evolution of the patent deposits in WIPO database.



Source: Data collected in the databases of WIPO (2016).

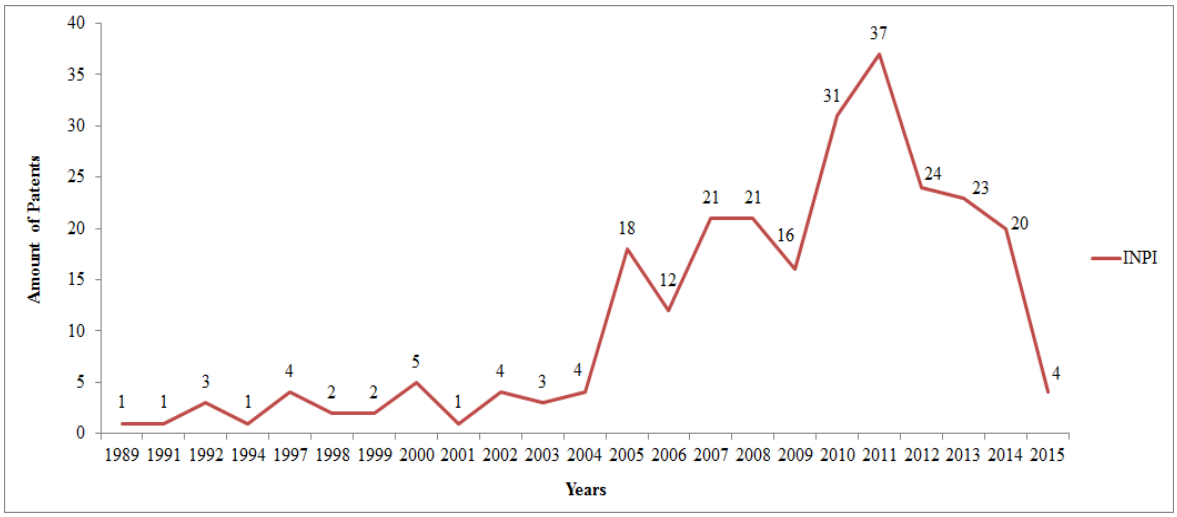
From 1986 to 1996, we can observe a low amount of patent deposits of embedded systems deposited on the WIPO database. From 1997, with the signing of a cooperation agreement signed between WIPO and the World Trade Organization (WTO), which aimed to establish a relationship of support and cooperation between the two organizations regarding intellectual property issues, the volume of patent deposits of this technology has grown exponentially over the years (Figure 1).

The period between the years of 2006 to 2014 were those who showed the greatest number of patent applications related to embedded systems, especially for the year 2008 presented 409 deposits of this technology.

The fall in the number of deposits of patents registered in the period 2015 to 2016 is related directly with the slowdown of the Chinese economy, as China is one of the countries that invest in the development of this technology patents in the world.

The first patent application of embedded systems identified in the INPI was registered in 1989 (Figure 2). The request was made by a French company, Societe Nationale Industrielle Aerospatiale call, who claimed a patent for a device that increased stability in helicopters with landing gear. The granting of this patent was granted in 6/29/1993 and since the 1/13/2004 the same day is extinct, due to the expiration of the term of legal protection.

Figure 2 - Annual evolution of the patent deposits in INPI database.

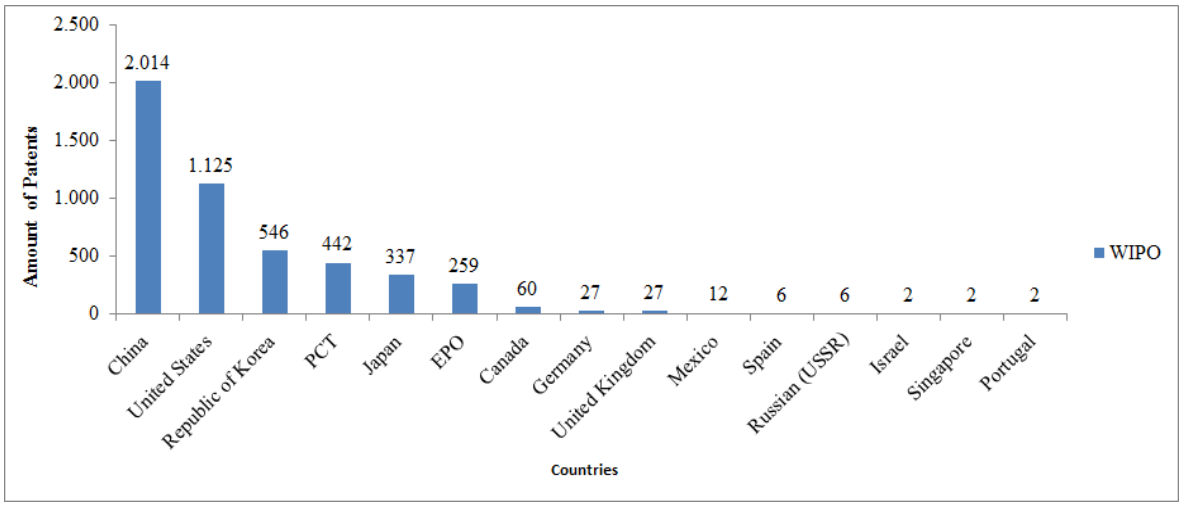


Source: Data collected in the databases of the INPI (2016).

Based on the data collected, the largest volume of deposits registered at the INPI occurred in the period from 2005 to 2014, with highlight to the year 2011 with 37. Already the smallest volumes were identified during the period from 1989 to 2004 and the year of 2015. In 2016, has not registered any deposit for patent search technology, as shown in Figure 2.

The ranking of the patent applications of embedded systems deposited on the WIPO database, is led by China with 2,014 deposits, followed by the United States with 1,125 and South Korea with 546 (Figure 3). The other countries cited in this research, although performing deposits for this technology did not highlight in relation to the quantity of patents deposited in this database.

Figure 3 - Number of patent deposits by countries in the database of WIPO.



Source: Data collected in the databases of WIPO (2016).

The data collected in this database shows the presence of patent deposits made via International Patent Cooperation Treaty (PCT) and by the European Patent Office (EPO), with 442 respectively and 259 deposits each (Figure 3).

It is important to note that has not been identified any embedded systems patent deposit held by Brazil in this database, although of the same being one of the Member countries of the PCT and patents developed this technology.

Table 3 highlights the countries which had the greatest number of deposits of patents related to embedded systems in Brazil (INPI). Note that of the 258 deposits identified on that basis, 217 were made by Brazil and 41 by foreign countries.

Of 41 deposits held by foreign countries, 29 checked in Brazil via PCT, 11 were deposited directly in the database of the INPI and only 01 performed via EPO.

Table 3 - Number of patent deposits by countries in the database of INPI.

Países	**INPI**
Brazil	217
France	26
United States	10
Germany	1
Netherlands	1
Japan	1
United Kingdom	1
Taiwan (China)	1
Total	**258**

Source: Data collected in the databases of the INPI (2016).

The foreign countries that had greater prominence in relation to the amount of deposits of embedded systems made in Brazil were: France, with 26 depots and the United States with 10.

The patent applications deposited in databases are sorted according to their technological area, through the system of International Patent Classification (IPC), as shown in Table 4. The IPC was created in 1971 from the Strasbourg Agreement and serves to sort the technical content of a patent application. The technological areas in the international patent classification system are divided into classes 08, represented by the letters A to H. In addition, each class is subdivided into subclasses and groups, through a tiered system. Currently, IPC has approximately 70000 registered groups.

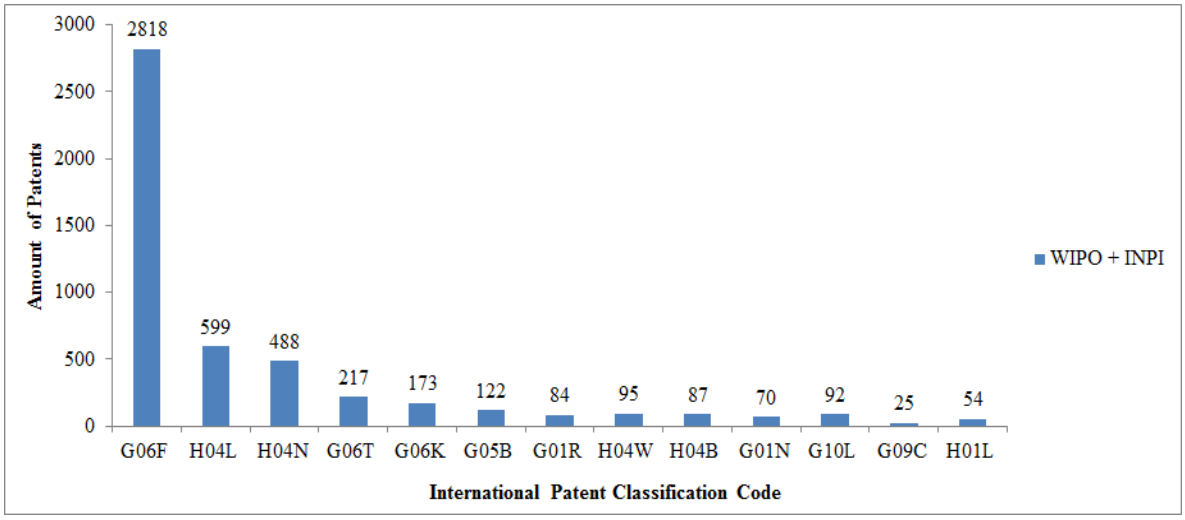
Table 4 - International patent classification (IPC).

Section	Classification
A	Human Necessities
B	Performing Operations; Transporting
C	Chemistry; Metallurgy
D	Textiles; Paper
E	Fixed Constructions
F	Mechanical Engineering; Lighting; Heating; Weapons; Blasting
G	Physics
H	Electricity

Source: WIPO (2016).

Based on the data collected in this research, we can observe that the international patent classification codes that identify with this technology are: H04L G06F, and H04N (Figure 4). The codes listed are described as follows in WIPO: G06F (G - Physics; 06 - Computing; Calculating; Counting; F - Electric Digital Data Processing; H04L (H - Electricity; 04 - Electric Communication Technique; L - Transmission of Digital Information and Telegraphic Communication; H04N (H - Electricity; 04 - Electric Communication Technique; N - Pictorial Communication and Television).

Figure 4 - Number of patents by the International Patent Classification (IPC).



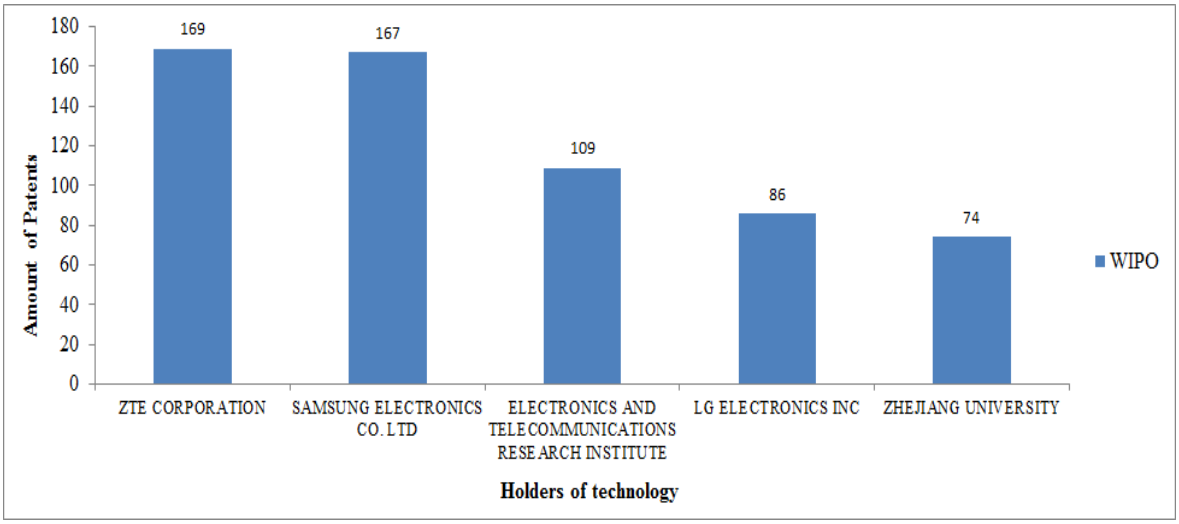
Source: Data collected in the databases of the INPI and WIPO (2016).

The IPC code G06F was that obtained the largest number of deposits, 2,818. Followed by H04L codes, with 599 deposits and by code H04N, which recorded 488

deposits. Other codes identified in this research did not show a significant amount of deposits for the representation of this technology, therefore were not cited in the analysis.

According to the World Intellectual Property Organization (WIPO), the most outstanding companies in the development of embedded systems technology were: the Chinese telecommunications company ZTE with 169 patents deposited and the Korean Group Samsung information technology area with 167 (Figure 5).

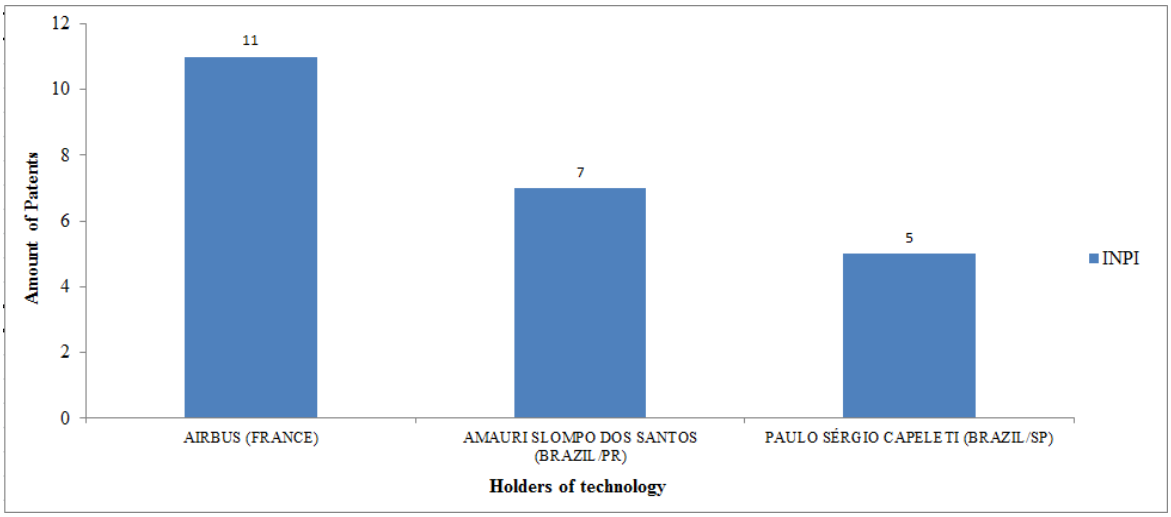
Figure 5 - Holders of patents deposited in the database WIPO.



Source: Data collected in the databases of WIPO (2016).

The brazilian database (INPI), we can observe that the biggest holders of patents for embedded systems were: the French company Airbus with 11 tanks and independent inventors, Amauri Sg dos Santos and Paulo Sérgio Capeleti, with respectively 07 and 05 deposits each, as shown in Figure 5.

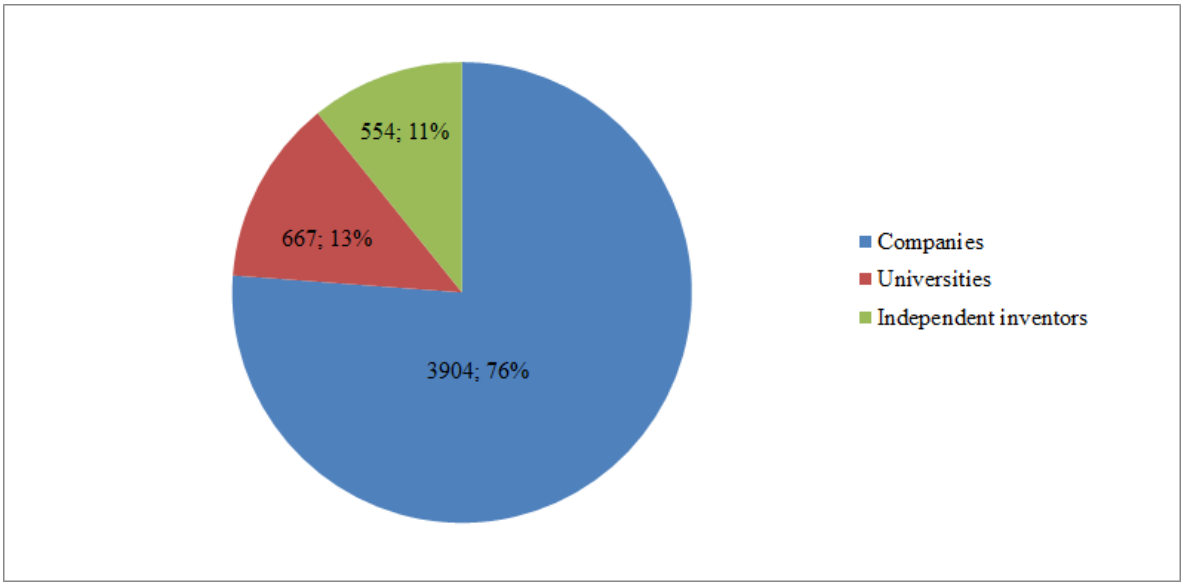
Figure 6 - Holders of patents deposited in the database INPI.



Source: Data collected in the databases of the INPI (2016).

Analyzing the profile of depositors of patents for embedded systems in the databases searched, we can observe that most 76% consists of companies, 13% by universities and only 11% for independent inventors (Figure 7). These data show the need for investments in the development of this technology in educational institutions.

Figure 7 - Profile of depositors in the databases searched (WIPO and INPI).



Source: Data collected in the databases of the INPI and WIPO (2016).

Final Considerations

The technological development in the area of embedded systems comes revolutionizing people's lives, providing more comfort, safety and agility in the execution

of various activities of our daily lives. Currently, the embedded systems can be found in most electricity-powered equipment.

The world market of embedded systems electronics industries demand a very accelerated production and diversified products, contributing in this way to the emergence of new projects and various research in that area.

The studies carried out in this work show that the market for this technology is in full growth, driven mainly by technological advances in the area of electronic components. Companies that invest more in the development of embedded systems belong to the telecommunications and information technology.

The largest investments in the development of embedded systems patents have been made for the international market. Currently, the countries that stand out in this scenario are: China, the United States and Korea. In these countries, government investments and companies in the areas of education and technological innovation are high.

In Brazil, the number of patents that technology is low compared with developed countries. One of the main reasons for this scenario is the lack of maturity of the country in the area of innovation and the lack of Government incentives and of companies in the development of research in the technological area.

Technological innovation is one of the determining factors for the development of the industry of a country. It stimulates the competitiveness and contributes to the strengthening of the economy and technological progress that society.

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