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Trend of Energy Saving in Electronic Devices for Research and Development

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Abstract. In electronic industry, energy saving is one of the performance indicators of competitiveness beside price, speed, bandwidth and reliability. This affects research and development (R&D) activity in mechatronic systems which uses electronic components and electronic systems. A review of trend of electronic devices technology development has been conducted with focus on energy saving. This review includes electronic devices, semiconductor, and nanotechnology. It can be concluded that the trend in electronic devices is mainly dictated by semiconductor technology development. The trend can be concluded as smaller size, lower voltage leading to energy saving, less heat, higher speed, more reliable, and cheaper. In accordance to such technology development, R&D activities in mechatronics especially in Indonesia is being pushed to make proper alignment.Some of such alignment actions are surface mount technology (SMT) for installing surface mount devices components (SMD), design layout and SMD troubleshooting tools as well as human resources training and development.

Keywords—energy saving; electronic devices; research and development; mechatronics; SMT; SMD

1. Introduction

Energy saving in electronic industry has become public intention. Energy saving is one of the performance indicators of competitiveness beside price, speed, bandwidth and reliability. This affects research and development of mechatronic systems which uses components and electronic systems. Therefore, a review of trends in technology of electronic devices and electronic systems is needed so that better planning can be done in the future.

These days principal of energy efficiency has enforced technology development to produce portable and high speed applications not to mention in semiconductor industry development. Each country has different focus on semiconductor industry. For example, SEMI Europe is focusing more on automotive, industry 4.0 and MedTech [1] while, semiconductor industry in Japan is focusing on household appliances [2]. The development of electronic technology is parallel to the development of the semiconductor industry which is triggered by high demand of new features of a product. Complementary metal-oxide semiconductor (CMOS) as the best semiconductor technology with low power consumption is producing more reliable and more efficient electronic devices [3][4][5][6][7][8][9].

This paper presents a review on electronic devices/components and electronic systems development with the focus on power efficiency and reliability.

2. Reviews

2.1 Electronic Devices and Semiconductor

Electronic devices development start in the 20th century. Existing innovations rooted from electronic components and semiconductors [10]. Three main components that being used are vacuum tube, transistor and integrated circuit [11]. History of electronic device development is shown in Figure 1 .

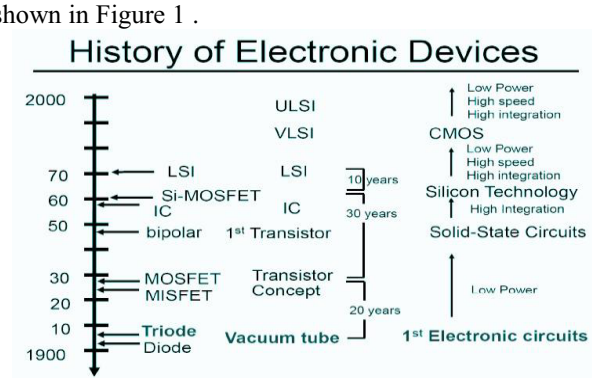

Figure 1. History of Electronic Devices [12].

In the era of vacuum tube, the size of a component is bigger than 1 mm. Vacuum tube was replaced by small dimension transistor that has low voltage. Most used semiconductor component are diode, transistor, field-effect transistor (FET), junction gate field-effect transistor (JFET), The metal-oxide-semiconductor field-effect transistor (MOSFET) and integrated circuit (IC). Electronic circuits in which the components are placed on printed circuit board (PCB) are called discret circuit. Electronic circuits in which the components are printed inside a silicon chip can be called as IC. To give background on how electronic device develops, generally in Table 1 is illustrated the comparison of electronic circuit design using integrated circuit.

Table 1. Discrete vs integrated circuit design.[13]

Activity / Item	Discrete	Integrated
Component Accuracy	Well known	Poor absolute accuracies
Breadboarding	Yes	No (kit Parts)
Fabrication	Independent	Very dependent
Physical Implementation	PC layout	Layout, verification and extraction
Simulation	Model parameters well know	Model parameters vary widely
Testing	Generally complete testing is possible	Must be considered before design
Computer Aided Design (CAD)	Schematic capture, Simulation, PC Board Layout	Schematic Capture, Simulation, extraction, layout and routing
Components	All possible	Active devices, capacitors, and resistor

Stated in [13] we know that compared to discret circuit, IC consumes lower, faster and better for signal related application.
Generally, packaging standard of semiconductors is based on Joint Electron Device Engineering Council (JEDEC) and Japan Electronic and Information Technology Industries Association (JEITA), whereas some companies use their own. Some purpose based semiconductor packages are available in [14]. Semiconductor packaging available nowadays is also for surface mount package.

2.2 Semiconductor Industry

The International Technology Roadmap for Semiconductor (ITRS) is a document produced by the group of world semiconductor companies from Europe, Japan, South Korea, Taiwan and United States. ITRS was designed and shown as technology rating without considering the individual commercial product [15].

2.3 Nanotechnology

Nanotechnology is a design and a production by implementing a system or a device in the scale of nanometer. Nowadays, miniaturization technology of semiconductor by using nanotechnology [16] has been implemented in countries dominating global semiconductor industry, such as Europe, Japan, South Korea, Taiwan and United States [17].

2.4 Observation of Electronic Devices Development in Indonesia

The development of electronic technology in Indonesia is parallel to the demand of users in the field of research and development (R&D). One of popular technology development is in the field of Robotic and Mechatronic. Figure 2 is an example of the implementation of IC in microcontroller. From left to right are shown the shift of microcontroller board with chips from ATMEL, the changes is not just from the dimension but also from its performance, size of the bit, working frequency and also features, as illustrated in Table 2.

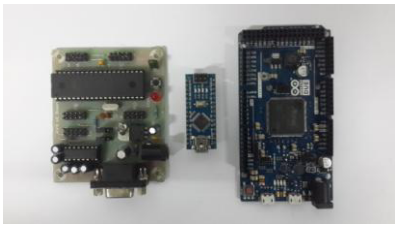

Figure 2. Microcontroller board used for R&D in robotic and mechatronics

Table 2. Example of Microcontroller Trend

Feature	Left	Middle	Right	Units
Technology	8	8	32	Bit
Chip size	Max.14 x52.5	Max. 7x7	Max.20 x20	mm
I/O	32	20	68	pin
RAM	2	2	96	KBytes
Flash Memory	32	32	512	KBytes
Max. Clock frequency	16	16	84	MHz
Max Operating Voltage	5.5	5	3.3	V
Power Consumption	At 1 MHz, 3 V, 25°C Active Mode : 1.1 mA Power-down Mode : < 1 µA	At 1 MHz, 1.8 V, 25°C Active Mode : 0.2 mA Power-down Mode : 0.1 µA	Low Power Mode Sleep and Backup Mode : 2.5 µA	

Figure 3 is motor controller circuit in which microcontroller, power supply, driver circuit for motor, signal conditioning ciruit for sensors are fixed in a PCB. This exposes an example of semiconductor implementation of electronic devices.

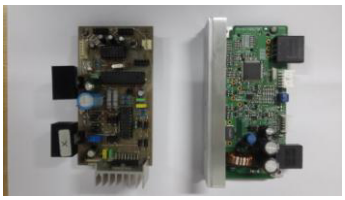

Figure 3. Motor controller including microcontroller, power supply, motor driver, and signal conditioning circuits

Table 3 has the completeness of features from motor controller circution in Figure 3.

Table 3. Motor Controller

Feature	Non SMD Circuit Motor Driver (Left)	SMD Circuit Motor Driver (Right)
Power Circuit	2 DC Voltage Regulator	DC Voltage Regulator 3-Phase power converter
IC Type	8 Bit Microcontroller Dual Full-Bridge Driver Stepper Motor Controller Max 232	ECU 3-Phase Motor Drive 8 Bit Microcontroller Op-Amp Passivated Bridge Rectifier
Max Current	4 A	> 10 A
Sensor	No Sensor	Hall Sensing

Clearly can be seen in Figure 3, nowadays the dimension of components is smaller. Surface mount device (SMD) component used in Figure 2 and Figure 3 while, the process of installing SMD components on PCB is using surface mount technology (SMT). One of assembling techniques being used is solder paste [18]. SMD components dimension is smaller than discret components. The design of small dimension electronic devices can be done because of this SMT technology.

3. Discussion

The trend of semiconductor technology for the producer takes place in term of product design, architecture, algorithm, software and evolution of life cycle [19]. The development of semiconductor is driven by the development of IC design. Design strategy of IC implemented nowadays is to reduce the complexity, increase productivity, and the guarantee of well-working product [14].

Semiconductor industry in United States is represented by SIA (Semiconductor Industry Association). Based on annual report of SIA in 2005 that there are more transistors are produced with cost lower than a grain rice [20]. A history analyst, Gordon Moore, estimates that the amount of transistor in a chip will rise exponentially [21-24]. In Figure 4 it is shown the development of transistor inside a chip.

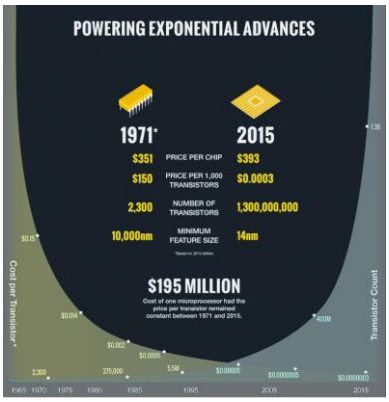

Figure 4. Transistor Development based on Law's of Moore [1]

From Figure 4 it can be seen data of the amount of transistor in a chip and the production cost of a transistor annually. Based on that data, the cost per 1000 transistors in 2015 is 0.0003$ cheaper than the cost in 1971 that was 150$.

In Figure 5 it is illustrated Intel's revolutionary 22nm transistor technology by Mark Bohr and Kaizad Mistry.

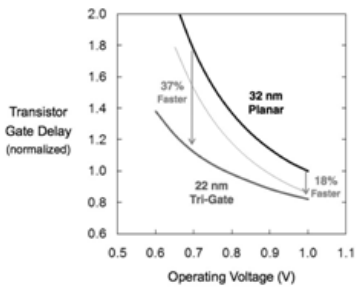

Figure 5. Intel's revolutionary 22nm Transistor Technology [25]

Three gate transistors when operated in low voltage will raise the performance as explained by Bohr [25]. Meanwhile in Figure 6 is illustrated the operating voltage of IC year by year.

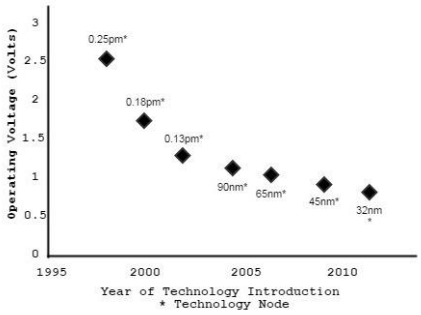

Figure 6. Energy saving performance of IC's year by year [26][10]

It can be seen clearly that in the 90's working voltage less than 5 volt has been introduced and micro technology was also being used. In the beginning of 2000, nanotechnology was started to be introduced, when the dimension of IC in the scale of nano then the working voltage was reduced to 1 Volt. The performance of IC is increasing parallel to its dimension. With the existence of

miniaturization, power consumption is lessen [27]. This implies larger energy saving as shown by Equation (1) [28].

$$P = ACV^2f + VI_{leak} \quad (1)$$

Where A is procentage of gate switching, C capacitance, V represents supply voltage, F = operating frequency, and I_{leak} for leakage current.

Figure 7 displays the document of ITRS about the development of semiconductor from 2002 to 2014.

YEAR	2002	2005	2008	2011	2014
TECHNOLOGY	130nm	100nm	70nm	50nm	35nm
CHIP SIZE	400mm²	600mm²	750mm²	800mm²	900mm²
NUMBER OF TRANSISTOR (LOGIC)	400M	1 Billion	3 Billion	6 Billion	16 Billion
DRAM CAPACITY	2GBits	10GBits	25GBits	70GBits	200GBits
MAXIMUM CLOCK FREQUENCY	1.6GHz	2GHz	2.5GHz	3GHz	3.5GHz
MINIMUM SUPPLY VOLTAGE	1.5V	1.2V	0.9V	0.6V	0.6V
MAXIMUM POWER DISSIPATION	130W	160W	170W	175W	180W
MAXIMUM NUMBER OF I/O PINS	2500	4000	4500	5500	6000

Figure 7. International Technology Roadmap for Semiconductors [12]

In the ITRS document it can be seen the development of semiconductor year by year and can be concluded that the future development of semiconductor will be low voltage, low power dissipation, higher working frequency, small dimension and packaging [29-30], the use of nanotechnology and more input/output (I/O) is available [31].

3.1 The Present and The Future

Small dimension allows more transistors to be packed into one chip [14]. This endorses semiconductor industry to adopt innovation miniaturization leading to nanotechnology. Based on Moore's law, miniaturization is approaching the limit and is now already to be used in nanoscale dimension. One way to overcome this limit is to combine the chip technology with a packaging technology that can accumulate chips into 3D integrated chips [22] [32-33]. When the dimension of IC became smaller electrical resistance, power density and thermal of the chips increase [34]. To overcame this case, normally IC is made dependent on the purpose and the workload [35].

3.2 Case Study

The limit of supporting components and mounting tools for low power consumption devices are current R & D obstacle. For example, in the process of R&D using brushless motor or other kinds of motor, the power supply used has 5 V of power, while microcontrollers that have full features needs 3.3 V. In order to solve such a problem, additional electronic circuits are needed to convert the voltage, illustrated in Figure 8.

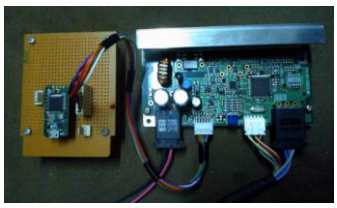

Figure 8. Solved problem of speed control brushless DC motor

4. Conclusion

Nowadays semiconductor development is the miniaturization of the dimension by using newest technology towards nanoelectronic < 50 nm. The technology trend can be shortened as smaller size, lower voltage, energy saving, less heat, higher speed, more reliable, and cheaper. Semiconductor low voltage and low power semiconductor can be accommodated using pure DC sources. It is expected that smaller circuits can be used for bigger benefit. In Indonesia, R&D activities in mechatronics is being pushed to make proper alignment. Some of such alignment actions are SMT technology for installing SMD components, design layout and SMD troubleshooting tools. For this human resources training and development is crucial.

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