Embedded Systems Architecture, the Sustainability of Our Technology World: An Analysis of the Design of Optimised Energy Metering Devices

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Abstract:

The technological world of the future will be built on embedded systems. Every major technical component contains embedded system components. Autonomous vehicles, smart architecture, automated production lines, aeroplane components, and smart grid energy systems are just a few examples. Embedded systems, or ES, are exactly what their name suggests: systems that operate within and improve the performance of other systems. This study explains the cutting-edge developments in this branch of engineering and shows how they affect practically every other aspect of technology in the twenty-first century. This article further zeroes in on contemporary energy metering designs, which have begun using embedded systems dynamics to enhance their functions, in order to present a clear picture of the good results given by ES Engineering and demonstrate its increasing importance.

Keywords: Terms Like "Embedded Systems," "Energy Meter," "Microcontroller," and "Programming"

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1. INTRODUCTION:

Rigid mechanical and electrical fixes to consumer concerns have given way to more flexible technologies. In order to get more nuanced outcomes, engineers have recently shown an interest in building fluid solutions that can collaborate with other adaptive characteristics. In the past, cars were simple electromechanical devices, but now they are technological marvels with countless microcontroller devices capable of processing millions of lines of code. It has been estimated that the numerous embedded controllers in a modern car run more than 100 million lines of code [1], all of which serve to improve the vehicle's efficiency in their designated roles. A wide variety of sectors, including aviation, medicine, agriculture, and the oil and gas industry, make use of this same technology.

Note that the micro computer controllers are a crucial part of the embedded system, which also includes other mechanical, electrical, and electronic parts. Over time, the term "embedded system" has come to mean a computer system designed to perform a specific task within a broader mechanical or electrical system, typically under strict real-time computing restrictions [2][3]. They are an integral component of a larger device, which may also have hardware and mechanical components. Embedded systems are the brains behind a wide variety of everyday objects [4]. To date, embedded systems have accounted for nearly 100% of all microprocessor sales [5]. Unlike general-purpose computers, which may be used for anything, embedded systems are designed to execute only the tasks for which they were intended, making them ideal for devices with extremely specialised needs. Because of the system's singular focus, designers are free to streamline it for maximum efficiency, resulting in a smaller, cheaper final product that can be manufactured in large quantities. To illustrate the magnitude of the potential savings, consider that this strategy might be applied to millions of individual items [6].

This article focuses on the specific area of Power Systems Digital Energy Metering in an effort to demonstrate the advancements made by this branch of Engineering in the realm of technology. As a byproduct of labour, energy is created. It is commonly understood to be the sum of all energy expenditures over a certain time period. An electric charge that can be put to use to perform work is what electrical engineers call "electrical energy" [7]. To that aim, it is helpful to keep in mind that the nature of the electrical energy at play here is determined by a number of analogue variables, most significantly current and voltage. These are the two primary factors in deriving the energy consumption throughout the given time period. Electricity metres work by continually measuring the voltage (volts), current (amperes), and finding the product of these two to give instantaneous electrical power (watts), and then integrating this value against time to give energy utilised (Joules, Kilowatt-hours etc.). Having these energy metres strategically placed makes it simple to assess hourly energy consumption rates. It also has uses in the systematic pricing of energy spent by individuals, among other things.

The study concludes with an explanation of the approach used to build and simulate the current energy metering system based on embedded systems dynamics. To further demonstrate the favourable effect brought about by the astute implementation of Embedded Systems Engineering in Power Systems, the study will compare and contrast the new metering system with the outgoing analogue metering system.

2. RELATED WORKS:

(a) White Paper By Surikit Jalali

An excellent introduction to embedded systems, covering their core components and application areas, was published in 2009 by Sukriti Jalali of TATA Consultancy Services in a white paper titled "The Trends and Implications in Embedded systems Development." Additionally, it surveyed recent developments and their implications for the future of these systems' design and development. Sukriti is an Engineer with over 15 years of expertise in designing and developing real-time embedded systems for a wide range of industries and applications, including [8] industrial automation, automotive electronics, transportation, and process control.

(b) A Peer Reviewed Paper By Ndinechi Et al:

A peer-reviewed study titled "Digital Metering System: A Better Alternative For Electromechanical Energy Meter in Nigeria" was written by M. C. Ndinechi, O. A. Ogungbenro, and K. C. Okafor in 2011. This study elaborates on the energy metering system that has been deployed in some regions of Nigeria, despite being shown to be exceedingly unreliable and resulting in a great deal of manual labour and time spent reading, calculating, and distributing bills. They brought up the growing demand for smart energy compatible metres and the importance of digitising the current Power Holding Company of Nigeria (PHCN) analogue metre. The paper provided clear examples of the steps used to create a digital metre with a cheap price tag.

Moving away from analogue conventions, the gadget is comprised of discrete components, a PIC, and a liquid crystal display unit, and it features voltage and current sensors as well as signal conditioning. A Peripheral Interface Controller and a ten-bit A/D converter are included into the PIC. PIC is a C-programmed embedded device since C is the language of choice for embedded devices. The layout shows hourly power consumption and monthly costs [9].

3. EMBEDDED SYSTEM:

The software (user interfaces, data processing, machine control) and hardware (I/O, Asics, DSP, FPGA) of an embedded system must be able to meet the rigorous requirements of real-time operation, dependability, maintenance, and cost-effectiveness. This is why there are two primary subfields within Embedded Systems:

- Embedded Software and
- Embedded Hardware

A couple of the most important subfields of Embedded Hardware include FPGA design for system on chip and PCB Design etc. Software development, including the creation of mobile applications and Embedded Operating Systems, falls under the umbrella term "Embedded Software." As a crucial piece of middleware, the operating system (OS) hides the details of the underlying hardware from the software programme and provides a uniform interface between the two. Operating systems also provide a streamlined interface to the various sensors and actuators used by embedded systems like smartphones, automobiles, and aeroplanes. The operating system on such machines must be as light as possible on resources like CPU and RAM. Real-time scheduling is another feature that must be included in the ES OS in order to provide service guarantees based on time limitations.

(a) Core Components:

Embedded systems consist primarily of the following components:

- Microcontrollers / digital signal processors (DSP)
- Integrated chips Real time operating system (RTOS) - including board support package and device drivers
- Industry-specific protocols and interfaces
- Printed circuit board assembly [8]

(b) Application Areas:

Embedded systems are used in a wide variety of contexts and can be found everywhere in the modern world. Embedded systems' primary use cases are outlined in Fig. 1.

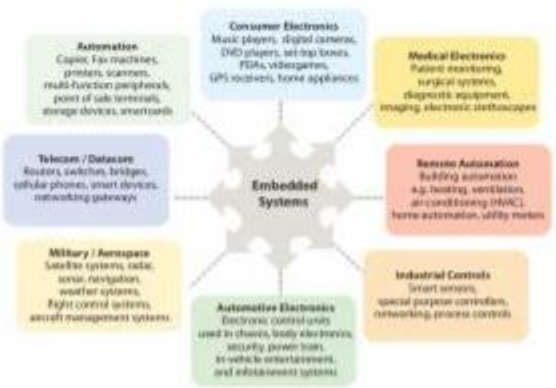

Figure 1 Major embedded system use cases [8]

(c) Perspectives on Embedded System Engineering in Africa:

According to the numbers, Africa has not yet made full use of this blossoming area of engineering. There isn't a single university in Africa that offers Embedded Systems Engineering at the undergraduate or graduate level. The course is, at best, an elective within the larger one, for which students receive a small number of credits in exchange for their time and effort. Although there are certain technical colleges that offer short-term training and certification courses in this area, it is regrettable that Africa does not have any degree-granting institutions in the subject of Embedded Systems Engineering at this time (2015). As a result, the number of Embedded Systems experts on the continent numbers in the hundreds, at most thousands, and most of the continent's larger embedded systems projects are typically contracted out to more advanced European businesses.

4. A CASE STUDY ON THE PRIMARY APPLICATION OF EMBEDDED SYSTEMS IN THE DESIGN OF A MODERN DIGITAL METERING SYSTEM:

The intersection of Embedded Systems Engineering and Digital Signal Processing is an important part of the field. As digital signals are processed and digital outputs are generated, the user and the developer are able to quantitatively evaluate the data being processed. This is why a more advanced and user-friendly metering system can be created through digitization.

To digitise the measured voltage and current, the PIC Microcontroller's high-resolution sigma-delta Analogue-to-Digital conversion capabilities is primarily employed. Then, the correct operations are performed on these numbers to obtain their decimal representations. Using a decimal multiplier on the voltage and current readings yields the instantaneous power in watts, while integrating this value over time yields the energy consumed, which is often expressed in kilowatt hours (kWh).

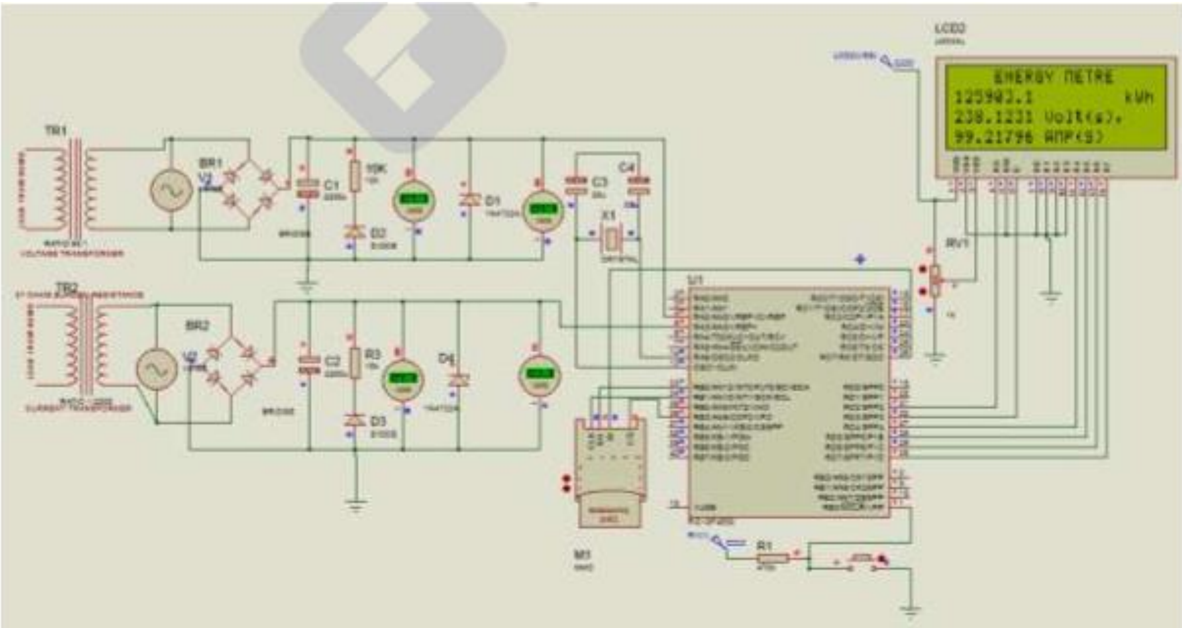

Figure 2 Energy Meter Schematic in Digital Form

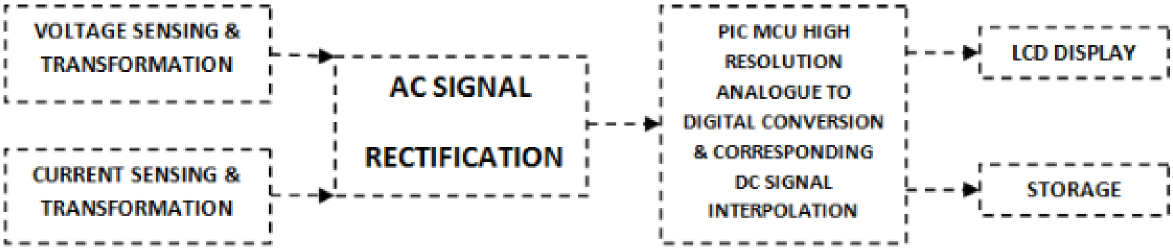

Figure 3 An overview of the Energy Metrics System's operation (in the form of a block diagram)

The steps in the metering process are explained in greater detail in the following sections.

(a) Voltage Sensing & Transformation Stage:

Around us, we encounter many electrical signals that are analogue. For a quantity to be directly related to another, it must change in tandem with that variable. It's common for voltage to be the first quantity discussed, whereas the second might be anything from heat to light to force to acceleration.

For the embedded systems digitalized metre, a voltage step down transformer with a 55:1 primary to secondary winding ratio is used for voltage sensing. The primary winding of this transformer is wired to receive power from the main electrical panel.

$$Vp/Vs = Np/Ns \qquad (1)$$

$$V_{PEAK} = \sqrt{2} * V_{RMS} \qquad (2)$$

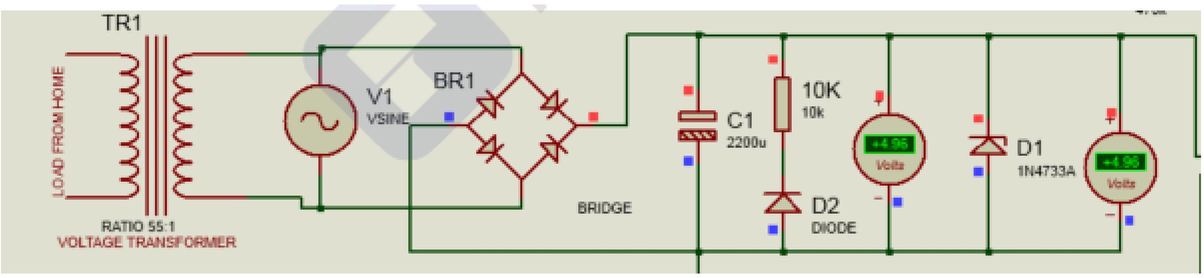

Figure 3 Conversion of Voltage System Diagram

4. Conclusion:

The digital energy metre is a great illustration of the beneficial impact embedded systems have on their host systems due to its compelling design example and optimum performance outcomes, both of which were founded on embedded systems implementations. As a result, the relevance of this branch of Engineering has skyrocketed. Medicine now uses embedded artificial human organs, diagnostic devices, patient monitoring systems, and surgical systems; the oil and gas industry uses ES to prevent pipeline vandalism. Cards with embedded electronic chips are being used for an increasing share of the bank's financial transactions and operations. ES is used in a wide variety of technologies, including satellites, smart buildings, home automation, weather systems, flight control systems, aviation management systems, and many more. As such, we can assert that Embedded Systems technology is, and has the potential to be, the epicentre of the 21st century's global economy.

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