# Instruction Level Energy Estimation of 8051 Microcontroller

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**Abstract:** Estimation of the energy consumed in battery powered applications is crucial factor in optimizing energy consumption of embedded systems. This paper proposes simple instruction level energy estimation for 8051 microcontroller based system for undergraduate level students. Energy estimation is very much important for any embedded system operating on battery. The measurement of the power associated with each instruction is carried out. Once the power cost of each instruction is known, energy consumed for any program can be easily calculated and various power saving methods can be adopted. An attempt is made in this paper to actually measure energy cost of each instruction of 8051 (P89LV51RD2) based system.

**Keywords:** Current measurement, embedded system, power estimation, software energy estimation.

## I. INTRODUCTION

Microcontrollers are used in various battery-powered applications. Their application area ranges from domestic to industrial applications like smart phones to remote transmission of numerous physical parameters useful in industries. Battery lifetime of embedded system used in these applications is very crucial. The microcontroller plays important role in determining this time. Embedded systems are being used everywhere and their demand is increasing rapidly. The main design targets for embedded systems are performance, area and low power consumption. In earlier designs, the focus was more on performance. Most of embedded applications are battery operated, being power critical, the emphasis is on power – performance tradeoffs. Software energy consumption, energy consumed during execution of software by the processor, plays vital role in the design of optimized software structure. In embedded applications, major part of power consumption is due to software [1]. To understand the impact of software on total power, the analysis has to start with the most basic level of software that is instructional level. Analysis at the basic level will help the undergraduate students to assess the software in terms of power consumed by it and to estimate power budget for the software.

A formula based on the Arrhenius Law suggests that life expectancy of component decreases 50% for every $10^0$C increase in the temperature. Thus, reducing a component's operating temperature by the same amount (consuming less energy), doubles its life expectancy. Thus by reducing the software energy, not only the time between successive recharges of battery is increased, but also battery life is increased. In addition to above, lesser power consumption reduces heat dissipation, resulting in low cost packaging, cooling methods and increases device reliability.

The power consumed by microprocessors has been a subject of interest and dealt in detail by various authors. The power consumed by the processor and the software executed by it has to be related. Hence the power consumed by the processor is different for different programs. Current microprocessors are complex systems with different task performing capabilities. This complexity can be visualized as hiding behind a simple interface, the instruction set [2].

Power consumption model of the software can be of two types: low level models and high level models. Low level models calculate power from electrical descriptions consisting circuit level, gate level, RT level. High level models deal with instruction and functional units from software point of view. High level power estimation models can be further categorized as Instruction Level Power Analysis and Functional Level Power Analysis.

The two main methods of embedded software energy estimation are: method based on measurement and method based on simulation. In second approach, a simulation model of the target hardware is used to run the applications and calculate the consumption of energy. Non availability of simulation model of all hardware modules and their cost, if available, are the main constraints. Measurement based approach use data obtained from actual measurements. Since real values are obtained from target flat form, the results are more accurate [3].

## II. PROPOSED APPROACH

The basic idea behind the approach is that certain instructions are executed repeatedly by the processor. Current drawn by the processor is measured. Knowing the voltage and current, power cost of these instructions can be calculated. Different techniques for current measurement have been proposed for estimating the power consumption in a processor.

The common approach used is to measure average current taken by each instruction executed by the processor. For more accurate results, instantaneous current of the processor is measured [3], [4], [5], [6].

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We can express the average power consumed by a microprocessor while running a program as product of average current and voltage

$$P = I \times V \quad (1)$$

where I is the average current and V is the supply voltage. The energy consumed by a program can be expressed as

$$E = P \times N \times T \quad (2)$$

where N is the number of clock cycles taken by the program and T is the clock period. Thus to estimate power / energy cost of the program, current drawn by the processor need to be measured. The average value of current can be measured by DMM available in lab or using data acquisition tool like NI DAQ.

In this paper, it is proposed to estimate instruction-level energy for 8051 microcontroller using the kit available in lab. 8051 microcontroller based P89V51RD2 is used. The P89V51RD2 is an 80C51 microcontroller with 64 kB Flash and 1024 bytes of data RAM. Since the basic purpose is to make the students aware about power budget, resources available in lab is used.
The most often used method is based on measuring voltage drop across a resistor inserted in the power supply line or ground line. A small value resistor is connected in between the power supply and the drop across the resistor is measured using DMM or myDAQ instrument. Using I=V/R, the average current can be calculated. Fig. 1 shows the approach used.

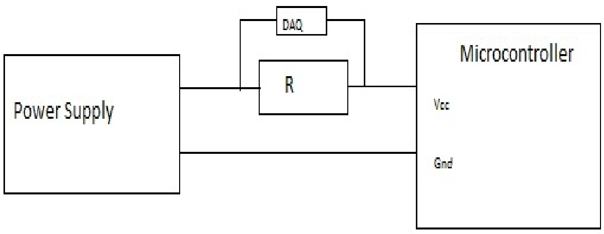


Fig.1. Block diagram of proposed approach

## III. EXPERIMENTAL MEASUREMENTS

Experimental setup consists of an 8051 (P89V51RD2) evaluation kit, DMM / NI LabVIEW software, NI myDAQ. In the set up the measurement of voltage drop is carried out in two ways, a) By using DMM and b) By using NI myDAQ instrument. The method used is based on the measurement of the average current drawn by microcontroller during the execution of the instructions.
In the proposed method, NOP instruction of 8051 is taken as base. Current taken from supply to execute NOP instruction repeatedly is noted. This current is the current taken by NOP instruction plus current taken by various components of evaluation board. Knowing power cost of each instruction, we can calculate energy cost of instructions. Power during execution of NOP found to be 712.576 mW and energy 59.3813 nJ. Similarly measurements were carried for various instructions of 8051.

## IV. EXPERIMENTAL RESULTS

Measurement results for different types of instructions are given below.

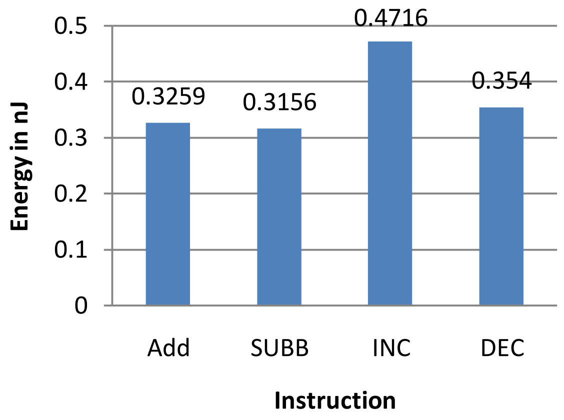


Fig 2 Energy estimation for Add, SUBB, INC & DEC instructions

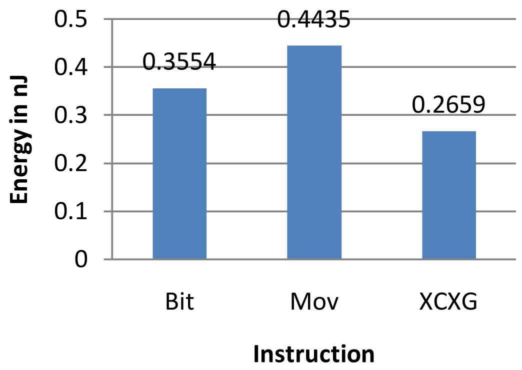


Fig 3 Energy estimation for Bit, Mov and XCHG instructions

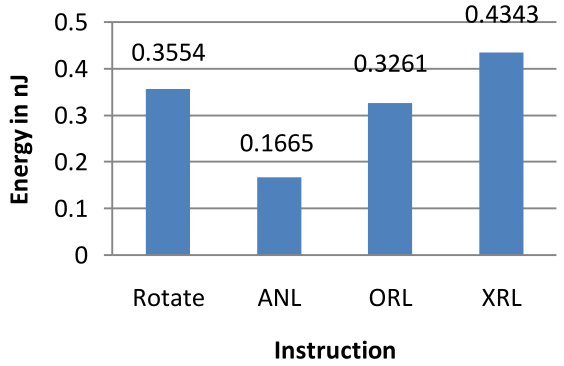


Fig 4 Energy estimation for Rotate, ANL, ORL and XRL instructions

Fig. 5 shows the energy estimation for different types of instructions of 8051. As can be seen from fig. 5, Program and Machine control set of instructions consume more energy followed by Arithmetic instructions, Data transfer instructions, bit manipulation instructions and Logical instructions.

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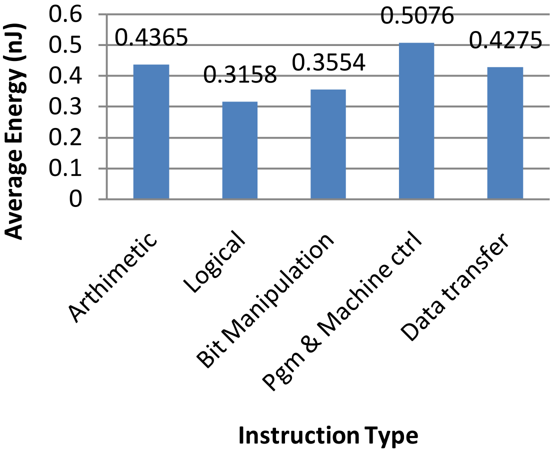


Fig5 Energy estimation for Arithmetic, Logical, Bit, Program & Machine Control and Data transfer instructions

## V. CONCLUSION

The Instruction level energy estimation can be achieved by monitoring average current of each instruction. Knowing the current the energy consumed can be calculated. A simple method is proposed. This method has been applied to 8051 based system. Resources available in lab are used to create "power budget" idea to under graduate students. A chapter on Power Management has been included in University curriculum.

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