DIGITAL ENERGY METER WITH A SMART CARD MODULE

The Concept, Design and Implementation by
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1 INTRODUCTION

It is a fact that electricity utility industry is one of the fastest growing industries especially in a developing country like ours. It is also no secret that the local electricity utility companies have been unable to keep up with expansion to the national grid especially when it comes to value added services associated with the selling of power. But when it comes to many other service industries like Mobile Communication and Banking a lot of instances can be seen where new technologies are integrated in many ways with their core businesses. One such area is the integration of the smart card technology with many products and services.

The main objective of our project is to integrate the rapidly evolving Smart Card Technology with the conventional billing system adopted by the electrical utility companies. In more specific terms it is to design and implement an add-on module for the conventional analog energy meter not only to make it display the total cost and the number of electricity units in real-time but also to store these values in a smart card so that billing process can be at least semi automated. Also this will allow the Electrical Utility Company to eliminate the need to employ meter readers to visit every electricity consumer in order to record the meter reading.

The main component in this project is a Micro Controller, which can be programmed to sense the number of revolutions of the conventional analog meter and calculate the cost online. The Micro Controller we used was DS5000, which is a variant of the 8051 Micro Controller family. Apart from the core 8051 architecture, this Micro Controller has an integrated Real Time Clock, a Bootstrap Loader and a battery maintained non-volatile memory for both Data and Code. The programming of the Micro Controller was done in 8051 Assembly Language and compiled using a Cross Assembler.

Currently both CEB and LECO are undertaking the Electricity Distribution in Sri Lanka and they are employing over thousand regular meter readers.

By upgrading the existing household analog meters with the above technology the Electrical Utility Company will be able to do away with the regular meter readers therefore saving a huge sum of money that is currently being expended as salaries. Also this technology allows the implementation of the following additional features.

- A credit limit that is customizable depending on the average electricity consumption.
- A time frame within which the customer should settle the bill.
- Circuit breakers can be utilized to automate the disconnection of the line after a warning upon exceeding the time and/or the credit limit.
- This will also facilitate the introduction of the time of the day tariff scheme.

From the point of view of the Electricity Consumers there will be the privilege of being able to know the electricity cost online. This will also motivate the consumer to reduce the consumption and also to compare various electrical appliances in terms of their power consumption. In the National scale this will contribute a lot towards saving of energy.

2 DESIGN

The design was carried out for a prototype that represented the actual model very closely but with slightly limited functionality and used components. The aim in designing the prototype was the least effort whereas in the actual model the main concern would be the economic feasibility and commercial viability. The main Circuit can be represented as a collection of several functional units as described below.

1. Revolution Counter
2. PC Interface
3. Micro-Controller
4. Display Unit
5. Smart Card Module

FUNCTIONALITY OF INDIVIDUAL MODULES

Revolution Counter

This block consists of an optical emitter-detector pair that is used to detect the number of revolutions that the disc of the analog energy meter rotates. A special Tone Decoder IC is used to detect only the modulated light rejecting the ambient light. Each revolution will generate a single pulse and continuous rotation will generate a pulse train, which will be fed to the Micro-Controller for counting.

PC Interface

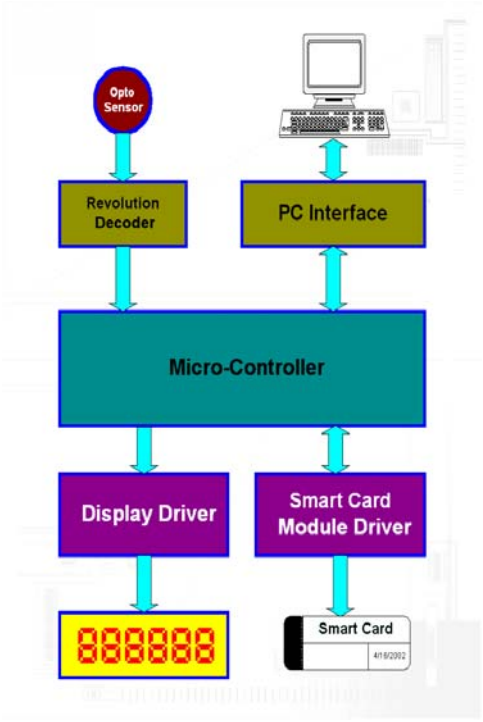
This is an optional module which is required if the customer opts for a PC interface which can be used for data logging as well as payment of the bill online using a credit card.

During the design stage this module has an additional purpose of facilitating the programming of the Micro-Controller.

Micro-Controller

This is the Brain of the Circuit. This will count the pulses that represent the revolutions of the energy meter and estimate the cost online, regularly updating the online display unit. End of every day the Micro-Controller will store the Number of Units and the Cost in the Smart Card Module. End of the Month (or week as set by the manufacturer) the consumer will be notified of the payment. Since this Micro-Controller is equipped with battery backed up non-volatile memory that can retain contents for a minimum of ten years sudden disruption to the supply power would not cause any unrecoverable losses to data.

BLOCK DIAGRAM



Display Unit

This consists of six 'seven segment' units that can display energy units or the cost up to a value of 999999. The choice of displaying the cost or the number of units is left to the consumer. In the prototype the 'cents' are not displayed in the cost display mode even though they are taken into consideration in internal calculations.

Smart Card Module

This is what makes this whole idea so unique and novel. In the prototype the Smart Card Module is represented by an EEPROM IC plugged into an IC base.
The concept of the Smart Card is to store data in some form of non-volatile memory contained in a portable card. Therefore our prototype can be easily extended to a real Smart Card by utilizing readily available Smart Card based EEPROM.

3 IMPLEMENTATION

Since the whole idea of the project is to incorporate the Smart Card Technology into the existing Energy Meter with a minimum change to the existing infrastructure the whole circuit is designed as an 'Add-on Module'. Therefore the existing analog energy meter is readily used with the only addition being the Opto Sensing Unit, which can be fixed inside the meter cover to sense the number of revolutions of the rotating disc.

Optical sensing ensures that there is no interference with the natural meter operations. The rest of the circuits are designed separately so that the consumer can fix it somewhere convenient to him/her, especially since the online cost/units display too will be in this unit. The interconnection with the Sensing Unit will be using only two slim wires. To ensure uninterrupted operation in an internal power failure this module is power by mains obtained at the meter terminals. Due to non-volatility of memory contents inside the Micro-Controller a supply failure at the meter would only cause the counting operations to stop until the power returns. A grid power failure would not cause any errors in the reading because the energy meter anyway stops during a power failure.

4 PROTOTYPE vs ACTUAL

The following additional features can be incorporated in the actual design with a very little effort.

- Eight Digit Display instead of the Six Digit Display. This will allow even the 'cents' component of the cost to be displayed.
- Actual Smart Card instead of the single EEPROM IC to represent the Smart Card.
- Incorporation of a Credit Limit and a Grace Period for the consumer.
- Automated Supply disconnection in the event of exceeding the above limits.
- Display for Power Consumption level

The main concern in designing the actual circuit would primarily focus on the economic feasibility and the commercial viability of the design, both of which took the least concern in designing the prototype. The next section discusses this issue further.

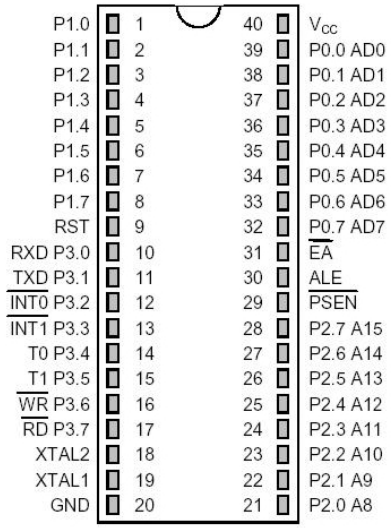
5 TECHNICAL SPECIFICATIONS

The central role of the design is played the Micro-Controller, for which we used a derivative of the famous 8051 family known as DS5000T manufactured by Maxim-Dallas Electronics, USA.

Features

- 8 bit 8051 compatible

- 8 or 32 Kbytes of nonvolatile RAM for program and / or data memory storage
- Initial downloading of software in end system via on-chip serial port
- Capable of modifying its own program and / or data memory in end use
- Crash proof operation
- Maintains all nonvolatile resources for Ten years in the absence of VCC
- Power-Fail Reset
- Early Warning Power-Fail Interrupt
- Watchdog Timer
- Software security feature
- Executes encrypted software to prevent unauthorized disclosure
- On-chip, full-duplex serial I/O ports
- Two on-chip timer/event counters
- 32 parallel I/O lines
- Compatible with industry standard 8051 instruction set and pin out
- Optional permanently powered real time clock (DS5000T)



40-Pin ENCAPSULATED PACKAGE

Pin Assignment Description

The DS5000T Soft Micro controller Module is a fully 8051-compatible 8-bit CMOS micro controller that offers "softness" in all aspects of its application.
This is accomplished through the comprehensive use of nonvolatile technology to preserve all information in the absence of system VCC.

The internal program/data memory space is implemented using either 8 or 32 Kbytes of nonvolatile CMOS SRAM. Furthermore, internal data registers and key configuration registers are also nonvolatile. An optional real time clock gives permanently powered timekeeping. The clock keeps time to a hundredth of a second using an onboard crystal.

6 CONCLUSION

Economic feasibility is the most vital factor governing the viability of a project. The current cost of a household energy meter is around 1500/= rupees, therefore it is essential that the add-on module we are introducing be priced at a comparative rate. The multi-functional DS5000T micro-controller that we used in the prototype alone costs few times the cost of an energy meter. The low cost alternative is to use the basic 8051 micro-controller instead of DS5000T in the actual design along with the necessary functional units implemented external to the micro-controller. This will help to bring down the total cost of the project to about 1500/= rupees, which we believe is fairly economical, compared to the long-term savings achieved by the electrical utility company mainly by being able to do away with the meter readers.

Apart from the economical advantages there are many social and other advantages in taking away the human factor involved in the meter reading process. The consumer will be spared of the inconvenience caused by the visits by the meter reader, and the errors introduced by the human factor will be largely reduced. By implementing the suggested improvements, line disconnection and reconnection can be fully automated sparing the hassle for the electrical utility company. A tariff scheme that takes into consideration the time of the day is essential to distribute the national load evenly throughout the day, which is vital for a country like ours where the load curve shows a lot of deviations throughout the day. The time of the day tariff scheme can be easily adopted with this design. Therefore it can be concluded that the pros outnumber the cons by a fair margin proving the project to be economically very much viable.

7 REFEERNCES

The main references were the data sheets downloaded from the online web portals of

- Dallas Semiconductor – www.dalsemi.com
- Maxim Products – www.maxim-ic.com
- Atmel Corporation – www.atmel.com
- Philips Semiconductor – www.philips.com
- Xicor Semiconductor – www.xicor.com

The following datasheets were primarily used:

- Secure Micro-controller Users Guide.
- 80C51 Programmer's guide
- 80C51 Instruction Set