

ENERGY HARVESTED ELECTRONIC SHELF LABEL

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Abstract: *This article explains the concept of electronic shelf labels in the e-retail domain. It also explains how a battery-less, energy harvested e-paper based ESL can be realized with ST dual EEPROM M24LR16E family, low power 8 bit MCU, the STM8L series , a L6920D boost converter IC and a few discrete components.*

Electronic Shelf Label (ESL), is a system where the price of a commodity is displayed and updated electronically. These are typically reusable modules with a low profile, and of credit card size. These display systems are attached mechanically to the racks holding the article. These systems mostly use Liquid Crystal Display (LCD) or OLEDs to show the applicable product price to the customer. A communication network, either centralized or manually operated, allows the display to be automatically updated whenever an article price is changed. This communication network can be based on different media, RF being most common, and also light-wave. Automated ESLs reduces pricing costs and improves pricing accuracy. Also, no print job is required each time an update is to be done; hence it is an environment friendly option as well.



Fig. 1 A commercial ESL

As we can see, a typical system above in Fig. is an ESL. This is based on a standard LCM. This has two implications:

- 1) It has a microcontroller based circuitry inside, which is always active. Whether it's displaying data (low consumption) or updating data (high consumption).
- 2) It requires a battery or some source of energy which has to be periodically replenished. It means again, a recurring cost and e waste.

The following figures are typical of electronic retail information systems.

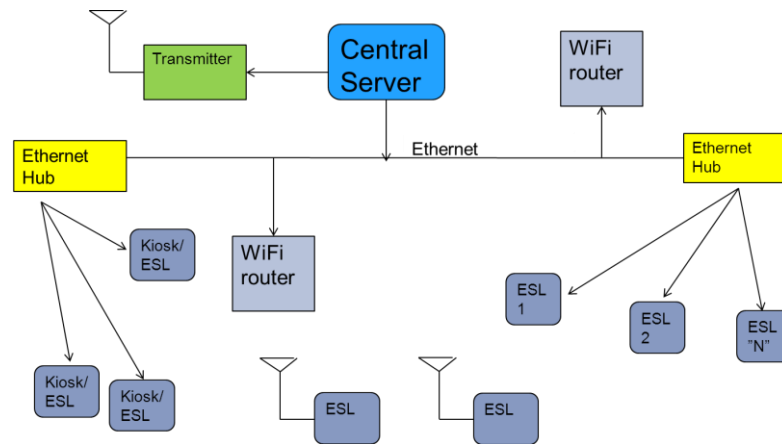


Fig. 2 Large Retail Information System

Figure 2 represents a large retail outlet scenario. These outlets may have dedicated servers, wired and wireless networks, and displays/labels ranging from miniscule tags to giant screens. These tags, screens or information kiosks are often powered over Ethernet, have significant data throughput and are capable of being updated from a centralized remote server. In all, a large system over a network with local or centralized monitoring and updating is in place for such scenarios. Sometimes, an entire mall can have its pricing and advertising information updated all at a time, or at predetermined times, governed by the store policy.

Figure 3 depicts a system which is much smaller in scale, typically for small shops, retail outlets and the neighborhood store. Here we have these labels, typically 2-3 inches in size. There is a handheld device or a NFC enabled smartphone which communicates with the labels and sends across the update information. These are mostly based on NFC/RFID principles.

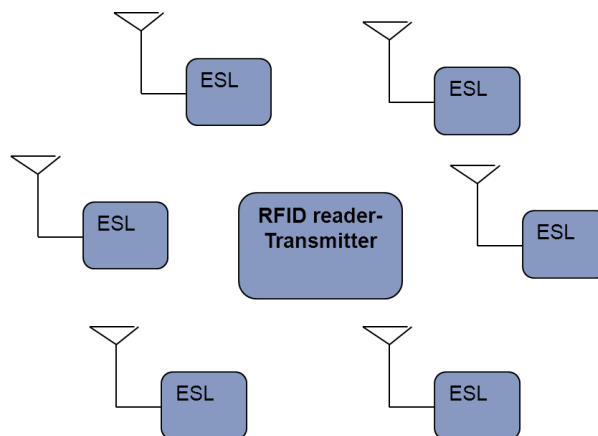


Fig. 3 Small Retail Labelling system

When an update is required, data is first fed to the RFID reader gadget or handheld device and when this device is close enough to the ESL, the updated data gets transferred to the ESL after authentication. Periodic maintenance like changing the battery is required in this case.

NFC and Smartphones:

Very briefly, NFC stands for Near Field Communication. It is a standardized wireless communication technology (defined by ISO 15693) used to exchange data between two devices when brought in close proximity, over a distance less than 10 cm is built over the concept of RFID technology. When NFC enabled devices are brought near to each other they get wirelessly connected by resonant inductive coupling.

Use of smartphones is growing at a very fast pace. Android phones with NFC capabilities are available in several price bands. Android applications for such phones can be developed to serve the electronic retail applications.

NDEF (NFC Data Exchange Format)

NDEF (NFC Data Exchange Format) is used in NFC based applications to exchange data between the nodes, which are NFC/RFID compatible. It is a standard data exchange format defined by the NFC Forum. NDEF Format is followed by applications to have a standard protocol of implementation. Using this format we can make our Energy Harvesting Android Application as NFC discoverable which means application will automatically launch on the phone when user bring it near to shelf label.

How to Get the Application on Phone?

Before we get to know the installation process of application, we must get a NFC compatible mobile phone. NFC compatible Android Application can be installed on the mobile phone. Android application developed for ESL is available as a .apk file which can be transferred to mobile phone through USB Mass storage mode. When the application is available in SD Card, it can be installed as a typical Android application.



Fig. 4 Smartphone and the ESL

How the Application Works?

The application can be used by the user to configure the dual EEPROM using NFC Compatible mobile phone. In shopping malls, it can be used to retrieve information about a product by just launching the application on phone and bringing it near to the price tag. Within a few seconds, one can have the information about the product, on the mobile phone. Once the content is available on phone, it can be shared through SMS, Gmail, Facebook or any social networking websites.

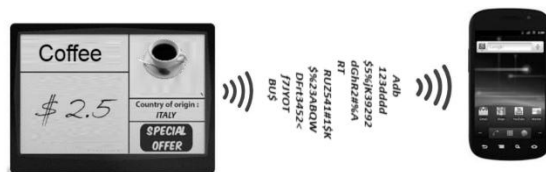


Fig. 5 Smartphone and electronic retail

Even further ahead is a concept, where the ESL itself requires no battery or source of power to operate. It is maintenance free and has a large number of possible update cycles. It is based on the concept of energy harvesting and e-papers. E papers are LCD like displays which can retain their display even after the power to them has been removed. Electronic paper, e-paper and electronic ink are display technologies which are designed to mimic the appearance of ordinary ink on paper. Unlike conventional backlit flat panel displays which emit light, electronic paper displays reflect light like ordinary paper, making these more comfortable to read, and offers a wider viewing angle compared to conventional displays. An ideal e-paper display can be read in direct sunlight without the image appearing to fade.

Coupled with energy harvesting, intermediate storage and subsequent energy conversion, it is possible to have battery less ESLs as shown in the picture below.



Fig. 6 A dual EEPROM based ESL with energy harvesting

The entire system is just as large as the display itself with the energy harvesting capability built in. The next section contains information on the system design aspects.

Design

These solutions are built over a fundamental concept in which both data corresponding to the image to be displayed as well as the energy required, to update the display, are provided by handheld device. RFID/NFC is one of the popular technologies to achieve this task. RFID/NFC supports a specific mode of communication in which out of two participating nodes, one might not have its own energy source and it takes part in the communication using the energy extracted from the magnetic field generated by the other node.

Further, if handled properly and efficiently, this intercepted energy not only enables the node to participate in the communication but also, if there is extra energy available (other than performing the communication requirements), allows the node to perform additional tasks with the extra energy. Solutions designed in this manner don't have any depleting power source or battery on board. In case of battery less

ESLs, the extra energy is used to update the e-paper with the text communicated via RFID/NFC technology. So the update data as well as power is supplied by handheld device which could be a RFID reader or a smart mobile phone. Such ESLs may be updated thousands of times requiring no periodic maintenance. The block diagram of such an ESL is shown in Fig.7 below.

ST’s RFID/NFC compatible dual interface EEPROMs enables to design and develop these kinds of applications, both data communication across NFC link as well as power generation, is handled by the dual mode EEPROM. These are basically contactless memories, with an I2C interface as well. Two such devices are available: The M24LR16E with 16Kbits of memory and M24LR64E, with 64Kbits memory.

In this design we have used the M24LR16E-R, which is organized as 2048 × 8 bits in the I2C mode and as 512 × 32 bits in the ISO 15693 and ISO 18000-3 mode 1 RF mode. The M24LR16E-R also features an energy harvesting analog output, as well as a user-configurable digital output pin toggling during either RF write in progress or RF busy mode.

These devices are available in many packages and are different from standard EEPROMs because apart from the I2C interface it has an RF interface and energy harvest feature as well. Data can be read or written over I2C or RF. During the process of data exchange, the internal energy harvesting feature, with its own rectification and regulation circuit allows extraction of energy from the incident RF field. The harvested voltage is made available on an external pin of the IC. Typically, 2.7V at 6-7 mA may be obtained. During the display update, the RFID/NFC reader/writer is brought close to the ESL. While the data is being written to the EEPROM, the energy harvesting pin keeps charging a super-capacitor. After the data is transferred, the voltage available across the super capacitor is boosted to 3.3V to drive the MCU and the ESL. Since very limited energy is available in the super-capacitor, the rest of the application must consume very little power. Hence, the system is based around a very low power 8 bit MCU the STM8L family. The STM8L151 device has been used here. During execution of the data read from EEPROM and display update functions, it draws only a few tens of microamperes. A point to note here: because of the inherent property of the e-paper, it requires a burst of current, in the order of several tens of milli-amperes, for a proper refresh. This burst typically lasts for a few milliseconds. This necessitates use of a super-capacitor with very low ESR. The typical value of the super capacitor might range from 0.2-1Farad, depending on the energy required.

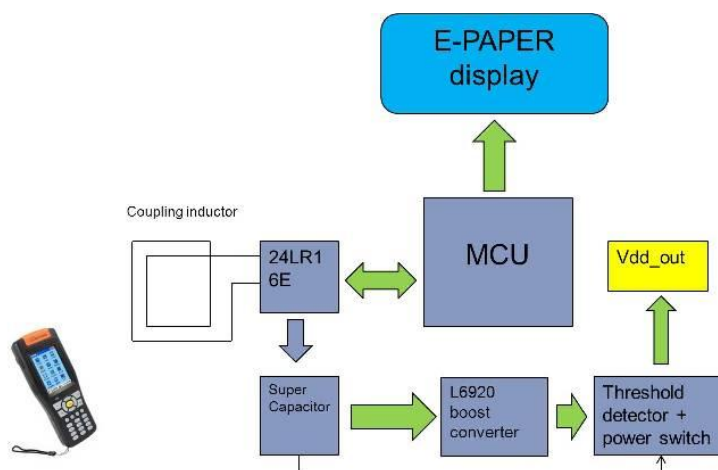


Fig. 7 Block Diagram of an ESL with energy harvesting

DC power is available from the EEPROM as long as the strength of field across EEPROM antenna (loop coil) is above a minimum threshold. Available energy is accumulated and then boosted to a suitable level, to operate the ESL module. The amount of energy captured, is dependent on the following:

- 1) The effective transmitted power from the RFID reader/smartphone
- 2) The effective surface area captured within the ESL antenna (on the receive side)
- 3) The distance maintained between the RFID reader and the ESL, during the ESL data update.

The final design is normally a tradeoff between all the three above. If the antenna size is made too large, then the overall ESL size becomes large. If the transmitter (RFID reader in this case) has to radiate more RF power, it means it drains its own battery much quicker. Smartphones, in order to conserve battery, have effective radiated powers much less than dedicated RFID readers. The net energy harvested has also a direct impact on the update time of the ESL. Higher field strength at the ESL antenna means the super-capacitor charges faster, and the update would be faster and vice versa.

(In this case, after the super-capacitor has started charging, the voltage across it starts rising gradually. The super-capacitor feeds the L6920D monolithic boost converter. (It starts working from 1V and keeps working down to 0.6V and is available in TSSOP8 pack.) So, till the voltage across the super-capacitor rises to a reasonable value, the V_{dd} to the STM8L and the display is isolated from the output of the L6920D. A 2STR2160 PNP transistor has been used as the power switch. For detecting the voltage across the super capacitor, another NPN transistor 2STR1160 with a diode has been used. After the super capacitor voltage exceeds 1.4 volts, the power switch is turned ON. The MCU is powered up, it reads data from the EEPROM, updates the e-paper display and goes to sleep. The process of updating the display depletes the stored charge from the super capacitor and makes the system ready for a fresh display update.

This type of solution can find many interesting applications ranging from labels in super markets to book stores to hospitals and other places where smart displays are required. Some other variants may be smart ID badges, status displays, electronic patient records etc.

References

- 1) Wikipedia
- 2) www.st.com
- 3) [L6920D datasheet](#)
- 4) [M24LR16E datasheet](#)
- 5) [STM8L reference manual](#)