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USE OF MOBILE FLASH-CARD STORAGES IN MEASUREMENT DEVICES AND SMALL AUTOMATION SYSTEMS

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Abstract – Mobile Flash-Cards in different technologies and formats are well suited to act as an exchangeable non volatile mass storage for data or program code in measurement devices and small automation systems [1]. Due to the use in the fields of digital photography and multimedia applications, flash cards have been introduced into the market and are available in a standardized and compact way. Because of their mobile characteristics, their solid-state design, security features and an easy handling, they are an appropriate storage medium in measurement data acquisition, but furthermore in the field of service and maintenance. This article is supposed to give an overview of the available storage media on the market as well as several ideas for the use in the field of measurement device instrumentation. In addition, the characteristics of the several flash cards are discussed, possible advantages and restrictions are compared.

Keywords: Flash-Card, Instrumentation, Automation- and Measurement Systems

1. INTRODUCTION

The ability to process, store and transmit digital data in a reliable form is one of the essential topics in the field of measurement and automation. The classical computational non volatile data storage is the magnetic-disk (hard disk). In addition to these methods, optical systems (CD, DVD) are established as dominant archival digital data storage.

Despite their numerous virtues, magnetic- and optical discs are not ideal for measurement devices and small automation systems. On the one hand, there is the size of the discs, which sets a lower limit to the devices designed to use them. On the other hand, the moving mechanical parts of these storage principles restrict the usage of these devices. They also require significantly more power than pure electronic devices. To avoid the above mentioned disadvantages, a flash memory is a good alternative. The flash memory is a non volatile, solid state, robust data storage, available in very small packages.

In a lot of field-applications there is no wired connection available, so there is the need to transport information physically between host computers and measurement or control systems in the field. So there is the need of a reliable, exchangeable, non volatile information storage like a floppy disk, which has been established as a standard.

Influenced by the commercial sector of digital photography and multimedia applications, such a standard is available. Standardized flash cards in many competing formats are established on the market. These products carry the potential to become the most widely used storage and interchangeable format for all kinds of digital information [2]. The field of measurement instrumentation and automation systems can benefit from the growing market of card technologies. Flash cards are interoperable between a lot of devices (PDA, Laptop), therefore they can store and retrieve data and exchange information with other devices. As there are no moving parts or batteries inside the cards, their data reliability, shock and temperature endurance enables the flash card to dominate the portable memory products market. Flash cards could be employed to send and deliver digital contents in an easy to use and small package, which could be handed even by unskilled personal

2. DIFFERENT TYPES OF FLASH CARDS

Before discussing possible applications, a short introduction to the flash card products is given [3]:

Fig. 1. Different types of standardized Flash cards

2.1. Linear Flash PC Card

Linear Flash PC Cards (specified by the Personal Computer Memory Card International Association, PCMCIA), were the first generation of credit card sized flash cards, introduced in the late 1980s. The cards provide 68 pins for electrical connection. In general, PC-

Cards are either available as memory cards in several technologies (ROM, RAM, FLASH), or as I/O cards (ATA disk-drives, network/modem cards). Depending on the card's thickness, PC-Cards are available in 3 different mechanical types (Type: I, II, II) in the range from 3.3, 5 to 10.5 mm. Independent from the card's technology, the characteristics of the card are described in a special memory area on the card, called CIS (card information structure).

Linear Flash PC cards are typically used in situations where they connect directly to the system bus and have direct access to the system CPU. In this XIP-mode (Execute In Place) the linear card must be capable of high-speed random access read operations. Therefore they requires internal storage for initial loader, BIOS, operating systems, and application programs. Linear cards can also be used to download data to main memory (RAM) controlled by the CPU in the host system.

Linear Flash cards are memory-mapped devices that serve needs for fast, random access working storage. They do not incorporate a build-in controller or use a pre-defined file structure, so data can be organized in any way that fits the application. This advantage means on the other hand that the host system must have special driver software that can interact properly to the Flash chip(s) used in the card. To accommodate a range of cards, portions of the software may vary according to the Flash device type, density and manufacturer. This may complicate the system design, limits versatility and concerns compatibility and reliability issues for product maintenance and after-sales support. As the cards only contain Flash devices and a rudimentary control circuit (typically an ASIC), a card-only cost advantage at low densities is provided.

Because of their long availability on the market, most of the laptops are equipped with a PC-Card slot. Besides this, a lot of PC-Card reader/writers with different interfaces are provided by several vendors. Therefore the programming of the cards in host systems has become very easy.

Fig .2. Compact Flash Card (CF) with a PC Card adapter

2.2. Compact Flash Card (CF)

CF cards (specified by the Compact Flash Association, CFA) were the first small form factor flash memory cards, introduced in 1994. These cards incorporate a build-in controller and are about the size of a matchbook. The controller on the card implements a IDE (Integrated Device Electronic) interface, similar to hard drives and ATA (Advanced Technology Attachment) PC-Cards. The cards provide 50 pins for electrical connection, which are a subset of the above mentioned PC-Cards. Therefore a passive PC-Card adapter (Type II or III) might be used to carry the CF in a PC card receiving frame. Similar to the PC-Cards, CF provides memory or I/O type cards in 2 mechanical dimensions (Type I,II) with 3.3 and 5 mm. Despite their small form factor, even I/O cards (Bluetooth, Ethernet) are available on the market.

In contrast to the PC-Cards, CF-cards provides a hard-disk like interface (IDE, ATA) to access their Flash memory. As defined in the standard, CF card are operable in 3 different modes: memory-, I/O or true IDE-mode. Whereas memory– and I/O- mode concern only the mapping of the CPU access to the CF-card., true IDE-mode means that the CF-card is directly connected to the IDE-bus and acts as a hard-disk replacement.

To avoid the above mentioned disadvantages of PC-Cards, CF cards incorporate an on-card controller which implements a standardized interface that allows the CF cards to operate as an external memory storage device without overhead on the system CPU or requiring special software. CF-cards are connected to the CPU's system bus through an interface similar to the one used for connecting disk drives to the system. For the system CPU, ATA Flash PC cards are the solid-state equivalent of a hard disk drive (HDD), and give access to the information stored in the card through main memory or I/O ports. ATA PC cards provide external storage for data such as new application programs, and application data files. They must be capable of rewriting data on a 512-Byte block base, which is equivalent to the capability provided by hard disks. The cards do not allow the CPU in the host system to access the Flash memory directly. Because of their ATA – interface, CF-cards can be used interchangeably in a variety of systems and products. The main differences between the linear Flash-cards and the CF-cards can be summarized in the following facts:

ATA cards aim primarily at file storage applications, whereas linear cards mainly intended for working storage applications. Linear cards are particularly effective for "execute in place" (XIP) system operation due to their superior random access speed. This speed is not necessary when they are only used to transfer files to main memory for processing by the host system CPU. On-card controllers ensure plug & play operation between a wide range of systems. Linear cards lack these on-card functions, which raises compatibility issues among different applications for users and requires driver support for all applications.

Fig .3. Smart Media Card (SM)

2.3. Smart Media Card (SM)

SM cards (specified by the SSFDC Forum), introduced in 1996, are the thinnest form factor flash storage devices. Originally called: Solid State Floppy Disk (SSFDC) as they look like a miniature floppy disk. They usually incorporate only one or two NAND Flash chip (s) and no build-in controller. Like Linear Flash cards, the host controller has to manage the appropriate read and write method. SM- cards perform best in file storage applications. As they use a proprietary NAND interface, they cannot be used as an ATA card. Since Smart Media Flash-cards contain just one or two Flash chips, they are obviously the most simple Flash-based non-volatile storage implementation.

However, this simplicity imposes a hardware and software burden on the host system, which must have a controller very similar to the complexity of an ATA controller. The card provides 22 pins for the electrical connection. The serial interface to the host system is used to transfer single addressed or sequential multiple data packages. Additional pins provide appropriate card status information. The software that runs on the Smart Media Card controller in the host system must vary according to card type and manufacturer because the operating specifications for Flash chips, such as those for reading and writing, vary between device types. A possible disadvantage for applications with this type of card is the mechanical sensitivity and the exposed contact plates which are very sensitive to contaminations.

To connect these cards to Host PCs, several adapters frames (PC-Card, Floppy-Disk) and card reader/writers are available on the market.

Fig. 4. Multi Media Card (MMC)

2.4. Multi Media Card (MMC)

MMC cards (specified by the Multi Media Card Association MMCA) are the smallest flash cards available. The MMC-card weighs less than two grams and with the size of a postage stamp it is the world's smallest solid-state removable storage device. Introduced in 1997, they incorporate a build-in controller. The packaging is a simple moulded package with a seven pad (pin) serial interface. The simple serial interface offers easy integration into various devices regardless of the microprocessor being used. The build in controller ensures 2 kinds of possible interfaces:

The first one is a serial synchronous protocol with a dedicated command pin. This mode provides even a bus interface with a bus master and up to 30 card-slaves with a dynamically distributed 16-bit address.

In the second possible mode, the card acts as a simple SPI (Serial Peripheral Interface) device with dedicated data-in and data-out pins. The data transfer from the card can be performed in two different modes. In the first mode, called streaming mode, the card transfers a continuous data stream. This mode is intended for multimedia applications. The second possible mode is the block mode, which transfers single blocks with a checksum. MMC-cards perform best in file storage applications. For this purpose, the standard describes the standardized file format structure of the card [4].

Fig. 5. Secure Digital Card (SD)

2.5 Secure Digital Card (SD)

SD card (specified by the Secure Digital Card Association SDA), introduced in 2001, are a second generation derivative of the MMC cards that are backward compatible to MMC. SD cards are slightly thicker than MMC cards and incorporate a build-in controller. Additionally to MMC card, cryptographic security protection is implemented. The card provides 9 pins for electrical connection. Seven of the nine pins used by the SD-card are the same as those of MMC. The additional 2 pins are used for data transfer (4 Bit, parallel mode). Therefore the card offers high speed data transfer up to 10Mbits per second. The high speed data transfer rate is intended to be used by audio or video applications.

In contrast to the other cards, there is a special secure area on the card. The content of this area can only be accessed with a secure encrypted data connection. Such as for the other cards, excepted for SMC, there are I/O cards (Bluetooth, GSM) available. SD-cards perform best in file storage applications. Because of their data transfer rates they are a clear favourite in video applications. To connect these cards to Host PCs, PC-Card adapters frames and card reader/writers are available. Even laptops with a SD-slot as standard equipment are offered.

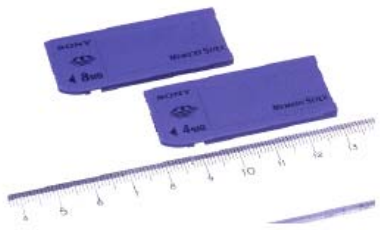

Fig. 6. Memory Sticks (MS)

2.6 Memory Stick (MS)

Memory Stick has been developed by Sony. The company has added memory stick capability to a wide range of products including digital cameras, digital camcorders and LCD TVs. But memory stick has also gained the support of more than 120 companies in the computer, consumer electronics, telecom and automotive industries. A memory stick is about the size of a stick of chewing gum. The stick provides 10 pins for electrical connection. A build in controller offers a serial data protocol. In addition, several pins act for status and security information (digital rights management). There are two types of sticks available which differ in colour. In contrast to the blue one, the white provides a "magic gate" which incorporates security issues.

There are a lot of PC-adapters available for connecting to a host PC. In addition, Sticks can be slotted into a floppy disk adaptor for PCs lacking a Memory Stick slot.

		SmartMedia	MMC	CFC	Memory Stick
					
Size		45x37x0.76mm	32x24x1.4mm	36x42x3.3mm	21.5x50x2.8mm
Weight		2g	1.5g	11.4g	4g
Vcc		2.7V ~ 3.6V/ 5V	2.7V ~ 3.6V	3.3V / 5V	2.7V ~ 3.6V
Power	Read	<20mA	<33mA	<45mA	<45mA
	Write	<20mA	<35mA	<60mA	<45mA
Data Rate	Read	15.0MB/sec	2.0MB/sec	10~15MB/sec	2.45MB/sec
	Write	2.0MB/sec	200KB/sec	0.3~1.0MB/sec	1.5MB/sec
Pin Counts		22	7	50	10
Interface		NAND Flash	SPI	ATA	Serial(Proprietary)

Fig. 7. Small card comparison by performance [5]

3. FLASH CARD APPLICATIONS

There are numerous applications for the use of a non volatile mobile data storage in the field of measurement, service and maintenance. As the cards are available in different storage capacities, it is possible to fit the card's density according to the different needs of the application. In most cases there is only the need for a receiving frame and not for a permanent flash card in the system. Some of the possible applications, which are already used in commercial measurement systems and others which are in the development state, are explained.

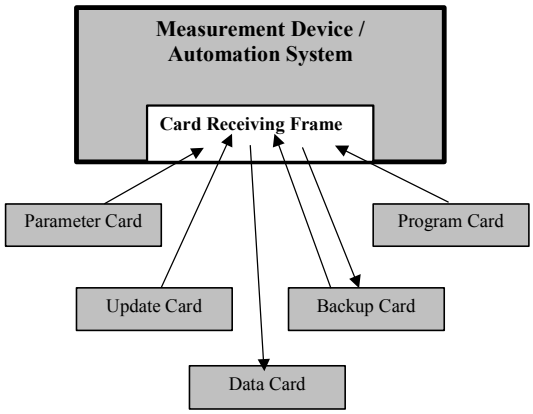

Fig. 8. Data flow Flash card application

3.1. Using flash cards as an Update Card

The intention of an Update card is to update embedded software of a system in the field without connecting the system with a PC. You only insert the card in a receiving frame. For updating the systems BIOS or initial loader, linear Flash cards are an appropriate storage medium because of their XIP functionality. Therefore no BIOS support from the target system is necessary. The update program as well as the BIOS code is stored on the card.

In most applications there is only the need to exchange higher software levels in the system. Supported by the local BIOS, all flash card types are able to act in this case as a source for the update of the system software parts. The choice of the appropriate card type should be taken in respect of the target system's characteristics (mechanical dimension, storage capacity, operating system).

3.2 Using flash cards as a Backup Card

In contrast to the Update Card, the Backup Card acts as an archival data storage. The purpose of such a card is to save important information which has been generated in the embedded system. The data on such a card could be distributed to other systems or downloaded in the original system to restore a certain storage state. As there is the need of writing data in the embedded system, it is advisable for this application to use cards with build in controller. The controller provides an interface for the system's CPU which is independent from the used Flash chips in the card.

3.3. Using a flash cards as a Program Card

The intention of a Program Card is to run temporarily another program on the system. The insertion of the flash card forces the system to execute the card's program and not the normal system software. This feature could be used for maintenance and service situations in the field. In this case there is the need to run special diagnostic programs, which are normally not shipped to customer.

Depending on the used operating system or execution model only PC cards with XIP functionality, or all the other flash cards are able to perform this application. The main advantage of this application is the fact that without reprogramming the system it is possible to execute temporarily other programs.

3.4. Using flash cards as a Parameter Card

On the one hand there are parameters which are linked with exchangeable system parts (sensor, actor). In case of exchanging such parts, offline prepared parameterisation (e.g. calibration data) could be installed by means of a mobile flash card. On the other hand, parameter sets for controlling different applications (product lines) stored on different flash cards are able to control the behaviour of automation systems. Both scenarios benefit from the advantage of mobile flash cards and allow offline customer specific configuration. As there is only the need for reading the cards information, all the discussed Flash cards are able to fulfil the needs. Only in the case of sensitive or secret data on the card, considerations concerning security issues should be taken. In this case cards with encryption features are preferred.

3.5. Using flash cards as a non-volatile Data Card

This type of application uses flash cards as a non volatile storage for dynamically generated data (e.g. logger). There are a lot of possibilities for such applications. Long time data acquisition, calibration history or operating hour counters are some examples for the use in the field of quality assurance. As there is the need for writing data in the embedded system, the same demands already discussed for the Backup-Cards should be considered.

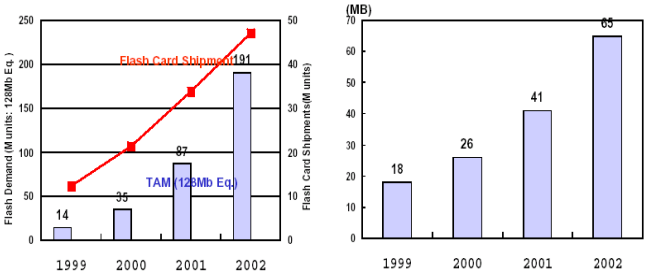

Fig. 9. Flash card shipment unit / average card density [5]

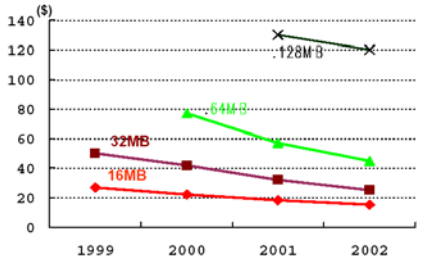

Fig. 10. Flash card price projection [5]

4. CONCLUSION

Experiences with the first flash card generation (PC Card) in several field-applications show numerous advantages of flash cards. Measurement devices and automation systems can benefit from the new flash card technologies. Because of the rapid growing market, the decreasing prices and the fast growing storage densities, it seems that Flash cards become the favourite non volatile storage media even in the field of automation. Using them can simplify data handling and reduces parameterisation efforts in the field of measurement, service, maintenance and quality assurance.

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