TECHNICAL BULLETIN

ULTRAVIOLET ERASING OF EPROM'S

The earliest electronic computers used a combination of semiconductor diodes and vacuum tubes to perform logic functions, and magnetic core circuits to perform memory functions. The initial transition to integrated circuits still left main frame computers in the form of magnetic core stacks—this was the last area within the computer to adopt solid state circuitry. The main reason was economic as core memory systems could be built at a cost less than that of other methods available at the time.

Rapid advances in Large Scale Integration (LSI) techniques and the decreasing cost of semiconductors in general reversed the conditions favoring core memory in the early 1970's. Increasing labor costs for the fabrication of core memory and the widespread proliferation and availability of low cost Metal-Oxide-Semiconductor (MOS) devices reinforced the trend in the mid-1970's towards semiconductors being the primary memory technology. Also, the inherent reliability of semiconductor memories led to their use in high performance applications in which core memory had proved unsatisfactory.

Now, the new memories are no longer limited to computers and have become a universal design element that is introducing the benefits of data storage to all electronics equipment industries.

Memory chips are everywhere: calculator manufacturers are putting them in programmable calculators for storing arithmetic programs; TV manufacturers are using them for storage channel frequencies; instrument manufacturers are using them; and makers of point-of-sale (POS) equipment are building them into on-line sales counter units that continously update inventory information. Even some sophisticated heart pumps contain EPROM's.

WHAT IS A SEMICONDUCTOR MEMORY?

The basic configuration of a semiconductor memory consists of a matrix of "cells" where data is stored. Various types of memory storage have evolved -- from simple diodes arranged in a matrix to gate and logic arrays, stored-charge devices and amorphous semiconductors.

Erasable memories use active transistor circuits as memory cells and are generally fabricated by MOS technology. MOS devices are classified according to different fabrication techniques, i.e. p-channel (P-MOS), n-channel (N-MOS) and complementary (C-MOS).

Two major classes of semiconductor memory have developed: Random Access Memory (RAM) and Read Only Memory (ROM). RAM is employed to store and retrieve digital data that is constantly changing in computer systems; ROM serves as a source of permanent data that is not lost when power is removed from the system.

Different system applications with their specific data storage applications have spawned the development of various categories of RAM and ROM memories, each with its own peculiar advantages and disadvantages. Only one of these will be addressed in this bulletin—the Ultraviolet-Erasable Programmable ROM, often abbreviated as EPROM or UV-PROM.

ROM generally signifies a mask-programmed ROM which obtains storage ability by virtue of the semiconductor manufacturing process. Data is permanently stored when the device is manufactured and cannot be altered. If an error was made in the mask (and the permanently programmed data), it almost invariably leads to the scrapping of the device. The procedure is also time-consuming and certainly not very well matched to today's rapidly changing technological advances. PROM's employ techniques that allow the complete device to be manufactured without programmed data and provide the user with access to input data. Data is inputted by a PROM programmer which accepts data either manually by keyboard or automatically from tape. Data is thus converted into the appropriate electrical format for the PROM being used. The nature of the PROM memory cells and the techniques required for programming vary with construction technology but always, unfortunately, once the bit patterns have been programmed into the memories they are permanent. The programmed PROM results in a device that is similar to a mask-programmed ROM — with the same disadvantages.

THE UV-ERASABLE PROM (EPROM)

The erasable PROM has a fused silica lid positioned above the semiconductor chip, which permits ultraviolet radiation to penetrate the semiconductor. The PROM is erased in this way rather than electrically as with RAM's, some ROM's and most recently with Electrically-Erasable-PROM's (EEPROM), also known as Electrically-Alterable-PROM's (EAPROM).

The first UV-erasable PROM was introduced commercially in 1972 by Intel Corporation and is known as the 1702A. It has the organization of 256 x 8 bits (2k bits) and is probably the most popular device, followed by the 2708 (8k bits) which was introduced in 1975. Devices with 16k capability emerged in 1977 and are being manufactured or are under serious consideration by a number of other manufacturers. More recently 32k devices have appeared and doubtless still larger memories are well on in development.

WHAT ADVANTAGES DO EPROM'S HAVE?

The attraction, of course, is the device's extreme usefulness in prototyping software codes in microprocessor designs. It typically takes several "passes" through a system before a program's code can be correct and optimized. Each "pass" requires a new program and a ROM that can be erased and reprogrammed quickly makes it much easier to optimize a program. For a complex project, erasable PROM's can save months of trial-and-error programming.

An additional dimension of flexibility has been added to systems design because,even when the programmer is satisfied with the program, it can be changed at a later date to accommodate new systems features. Alternatively, the user can switch to mask-programmed ROM's or can program ROM's with identical pin assignments and power supply requirements.

In practice EPROM's are being increasingly designed as a permanent part of a system because of the severe price war that has resulted in prices that make them very competitive with the less flexible, non-erasable PROM's and ROM's. Lengthy turnaround times for custom-programmed circuits are avoided and they are now appearing in many unanticipated small volume production applications (even though they may never be programmed again), as well as for prototyping. Once the right program has been found, other UV-erasable PROM's may be programmed to duplicate the bit pattern of the prototype.

Ultimately, ROM's manufactured from specific masks to duplicate the bit pattern would be substituted for large production runs. In the latter case, the experimental EPROM would then be erased and moved to another experimental location.

HOW DO EPROM'S WORK?

The basic memory element was developed by Frohman-Bentchkowsky at Intel Corporation and was known as the Floating-Gate-Avalanche-Injection MOS (FAMOS) transistor. It was essentially a silicon gate MOS field effect transistor in which no connection was made to the gate. The gate was in fact electrically "floating" in an insulating layer of silicon dioxide. The devices have been fabricated in two structures: p-channel or n-channel. The p-channel devices were the first EPROM's available commercially,but many devices are now using n-channel technology. N-channel MOS devices have the advantage of being able to function with a single power supply.

By application of a sufficiently large potential difference between the source and drain, charge can be injected into the "floating" gate which induces a charge in the substrate. The source-to-drain impedance changes and a "p-channel" or "n-channel" is created, depending upon the type of substrate. The presence or absence of conduction is the principle of data storage. Application of high-intensity ultraviolet light causes the gate charge to leak away and restores the device to its original unprogrammed state.

WHAT IS ULTRAVIOLET LIGHT?

Ultraviolet light is an invisible band of electromagnetic radiation beyond the violet end of the spectrum. It extends from a wavelength of 0.1 to about 380 nanometers(nm), although the region between 180 and 380 nm is the only part that is normally experienced because of the absorption of shorter wavelengths by air. The wavelength of specific interest in the UV-EPROM application is 253.7 nm, which is often rounded off to 254 nm. The equivalent numbers in alternative units of measure are:

2,537 Ångstrom Units (ÅU)
253.7 Millimicron Units (mμ), also rounded off to 254 mμ.

HOW MUCH ULTRAVIOLET LIGHT IS NEEDED?

The time required for complete erasure of the information on a cell is very consistent from device to device, provided that the fused silica window is clean and there are no pieces of dirt or silicon chips on the surface of the EPROM. In these cases the shadows reduce the amount of ultraviolet light falling on those cells obscured by the obstacle, thus increasing the time required for complete erasure. Awareness of the problems, and screening followed by careful cleaning of the fused silica window, can minimize the required times. For maximum irradiance at the chip, the lamp should also be kept clean of grease and other ultraviolet-absorbing materials by periodically wiping it down with a solvent such as alcohol.

The minimum erasing time in seconds is obtained by multiplying the nominal erasing energy (W-sec/cm²) by 1,000,000 and dividing by the ultraviolet irradiance at the chip (in microwatts/cm²).

$$\text{Time (secs)} = \frac{\text{Nominal Erasing Energy (W-sec/cm}^2\text{)} \times 1{,}000{,}000}{\text{Irradiance } (\mu\text{W/cm}^2)}$$

Many EPROM manufacturers have assigned nominal erasing energies to their devices to assist the user in determining the optimum erase time. They have been specified as requiring 6,10,15 or even as high as 25W-sec/cm² of ultraviolet energy for complete erasure. Some manufacturers, however, do not specifically provide this information, but the values are probably much the same as those given for equivalent devices made by other manufacturers. Spectronics Corporation has striven to make the following table as comprehensive and as accurate as possible. The presence of a manufacturer or part number on this table is not an endorsement of the product.

Manufacturer	Type No.	Nominal Erasing Energy (W-sec/cm²)
Intel	M1702A	6
	1702/1702A	6
	1702A-2	
	2704	15
	2708	15
	M8702A	
	M2708	15
	M8708	
	2716	15
	2732	
	2758	
	8704	
	8708	
	8741	
	8748	15
	8748-8	
	8755	15
National	1702A	
	MM5202AQ	6
	MM5203Q	6
	MM5204Q	6
	MM2708	15
	2708/8708	
NEC	2716	
Fairchild	2704	
	2708	
	2716	
Intersil	IM6603	
	IM6604	
AMD	Am1702A	6
	Am2708	10
	8748	

Manufacturer	Type No.	Nominal Erasing Energy (W-sec/cm²)
Mostek	MK3702-1	6
	MK3702-2	6
	MK3702-3	6
	MK2708	10
Texas Instruments	TMS2708JL	10
	TMS27L08JL	10
	TMS2716	10
	TMS2516	10
	TMS2532	
	9940	
Fujitsu	MB8518E	10
	MB8518H	10
Signetics	2708	15
	2716	
AMI	S6834	
	S6834-1	
	S5204A	
Electronic Arrays	EA2704	25
	EA2708L	
	EA2708M	
	EA2716	
Motorola	MCM2708L	10
	MCM27A08L	
	MCM2716L	
	MCM2716AL	
	MCM2717L	
	MCM68708L	
	MCM68A708L	

SIMULTANEOUS ERASING OF SEVERAL EPROM'S

The published erasure times given by some EPROM-erasing lamp manufacturers are optimum times based on the ideal situation of one EPROM at the point of maximum irradiance. Because of the inadequate explanation of this fact, some confusion has arisen when simultaneously erasing several EPROM's, and incomplete erasure of one or more EPROM's has occurred. The programmer has been uncertain as to whether the lamp was functioning incorrectly or that perhaps the chips were bad. There could be an alternative explanation and it is the purpose of this bulletin to explore the situation when erasing several EPROM's simultaneously.

The irradiance produced at the surface of the EPROM chip is dependent upon where and how it is located with respect to the tube of the lamp. For example, if it is located off to the side and near to the end of the tube it receives considerably less erasing energy than an EPROM located directly below the center of the tube. Usually this latter location is that chosen by lamp manufacturers when specifying erasure times. However, these figures are usually meaningless if the lamp is loaded with more than one EPROM, because obviously only one chip can receive the maximum irradiance. The relevant parameter is the time needed for erasing all of the EPROM's—including the worst placed EPROM (i.e. the EPROM receiving the least amount of 254 nm energy per unit time).

The following table provides data concerning estimated erasing times for the least favorably situated EPROM:

ERASING TIME REQUIRED, IN MINUTES

NOMINAL ERASING ENERGY	PE-14, PE-14T			PE-24T			PL-265T			PR-125T, PR-320T PC-1000, PC-2000	PC-1100, PC-2200 PC-3300, PC-4400
	1 EPROM CHIP	4 EPROM CHIPS	6 EPROM CHIPS	1 EPROM CHIP	3 EPROM CHIPS	9 EPROM CHIPS	2 EPROM CHIPS	10 EPROM CHIPS	20 EPROM CHIPS	1 CHIP TO FULL CAPACITY	1 CHIP TO FULL CAPACITY
6W-sec/cm²	19.2	21.2	23.6	14.9	15.6	19.5	14.9	15.6	19.5	6.7	6.3
10W-sec/cm²	32.0	35.3	39.3	24.9	26.0	32.5	24.9	26.0	32.5	11.1	10.4
15W-sec/cm²	48.0	53.0	59.0	37.3	39.0	48.8	37.3	39.0	48.8	16.7	15.6

IMPORTANT: The above erasing times are based upon typical peak irradiances of the erasers and are given only as estimates — actual erasing times may vary. The suggested operating procedure is to use the above table to select the estimated erasing time and then vary the exposure period until you determine the minimum amount of time required for complete erasure.

As with all metal vapor discharge lamps, the output of the ultraviolet tubes and/or grids in our EPROM erasers will gradually decrease throughout their life. Use of the Spectroline® DM-254X Short Wave UV Meter is recommended for monitoring intensity levels over time, so that optimum erasing times may be properly maintained. Please contact the factory for complete information.

HOW LONG DOES IT TAKE TO GIVE 1 WATT-SEC/CM²?

Some manufacturers express the EPROM erasing speed in terms of the time it takes a lamp to deliver 1 Watt-sec/cm² to the EPROM chip. Again, this has usually been given for only one EPROM placed in the best possible position. For completeness and accuracy as well as for its practical application, the data will be given for all of the configurations mentioned above.

The following table provides data concerning estimated times needed to deliver 1W-sec/cm² of energy to the least favorably situated EPROM:

	PE-14, PE-14T			PE-24T			PL-265T			PR-125T, PR-320T PC-1000, PC-2000	PC-1100, PC-2200 PC-3300, PC-4400
	1 EPROM CHIP	4 EPROM CHIPS	6 EPROM CHIPS	1 EPROM CHIP	3 EPROM CHIPS	9 EPROM CHIPS	2 EPROM CHIPS	10 EPROM CHIPS	20 EPROM CHIPS	1 CHIP TO FULL CAPACITY	1 CHIP TO FULL CAPACITY
Time Required to Deliver 1W-sec/cm²	192 sec	212 sec	236 sec	149 sec	156 sec	195 sec	149 sec	156 sec	195 sec	67 sec	63 sec

DOES THE EPROM WEAR OUT?

It has been noticed that repeated erasing and reprogramming of EPROM's appears to increase the required erasing time. Not much has been published regarding this phenomenon because EPROM's are usually not cycled that large a number of times—it can only be speculated that possibly some chemical changes take place within the device. The one thing that is certain is that it is dependent upon the erasing and programming techniques. Well over 100 programming and erase cycles still resulting in a usable EPROM have been reported in literature (1) using certain programming techniques and equipment, yet some reports have indicated only 30 to 50 times using other techniques.

Attempts have been made to "recondition" the devices by baking them prior to erasing—this technique has resulted in some reduction in the erase time. However, no method has gained widespread acceptance or recommendation because of its very limited need.

CAUTION

All Spectroline EPROM-erasing lamps and cabinets are provided with a safety interlock mechanism to protect against accidental exposure of eyes or skin to hazardous short wave ultraviolet light. Operation of the eraser is prevented unless the tray or drawer is fully and properly inserted into the housing. Any attempt to defeat the safety interlock may result in painful eye and/or skin burns or other harmful effects.

REFERENCE

(1) "How to Use 1702A MOS PROM's Reliably," Edwin Lee, Pro-Log Corporation, 2411 Garden Road, Monterey, California, August 1975.

NOTE: The above data was compiled in December 1980 and subsequent changes in any of the Spectroline EPROM erasers may affect the data.