

**Application of Intel's
5V EPROM and
ROM Family for
Microprocessor
Systems**

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Application Engineering

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Contents

INTRODUCTION	1
PINOUT EVOLUTION	1
SYSTEM ARCHITECTURE	1
BUS CONTENTION	2
THE MICROPROCESSOR/MEMORY INTERFACE	3
TERMINOLOGY	3
THE NEW INTEL FAMILY	4
PRINTED CIRCUIT BOARD DESIGN	6

INTRODUCTION

This Application Note discusses how the new Intel family of 5 volt EPROMs and ROMs can be used with microprocessor systems. The pinout evolution and philosophy are explored in detail, which leads directly to system architecture. Particular emphasis will be placed on the pitfalls of bus contention and the microprocessor/memory interface. Finally, an actual printed circuit board layout is presented.

PINOUT EVOLUTION

As EPROM/ROM technology has evolved, there are often periods of confusion over EPROM and ROM pinouts, as ROM density usually leads EPROM density by a factor of two, but ultimately users want any given EPROM to have a ROM compatible part. As we have seen, after the 2716 16K EPROM was introduced, a new ROM pinout emerged and “triumphed” over an earlier “standard.” The reason this ROM pinout change occurred is that as codes stabilize in user’s systems and equipment, many users opt for the less expensive ROMs, which are mask programmable devices. At the same time, users often use the highest available density ROM so they combine modular firmware and minimize device count. Of course, many users never do go to the ROM stage with their equipment, preferring to minimize inventory levels and utilize standard designs that can be customized for final equipment configurations, but they always want the capability to do so if desired.

In addition, over the past few years, the development of microprocessors has been intimately entwined with both ROMs and EPROMS.

The 1702A and its ROM counterpart, the 1302, were completely adequate to support the requirements of the 4004 series of microprocessors. In order to support the 5 volt, 3MHz 8085A and 5MHz 8086, it is desirable to use a compatible device such as the Intel 5 volt 2716, whose 450ns access time is compatible with the microprocessor requirements. Some high performance versions of these processors may require selected versions of the 2716 (such as the 2716-1 with $t_{ACC}=350ns$, or the 2716-2 with $t_{ACC}=390ns$) depending on the actual system configuration.

Summarizing these events since the introduction of the Intel 1702A, which was the first EPROM, we can postulate the following hypothesis: at any point in time, the present EPROM determines the pinout for the next generation ROM. And, if the subsequent larger density EPROM is not ROM compatible, the ROM will change. Also, it can be seen that ROMs and EPROMs must evolve along with microprocessor developments—so memory performance does not limit system performance.

The devices which are discussed in this Application Note represent an extension of the 5 volt compatible family to 32K bit and 64K bit densities, while improving performance as discussed above. It also follows that the pinout

for the 32K devices must be derived from the 2716 in order to maintain socket compatibility. This 16K to 32K pinout evolution is shown in Figure 1.

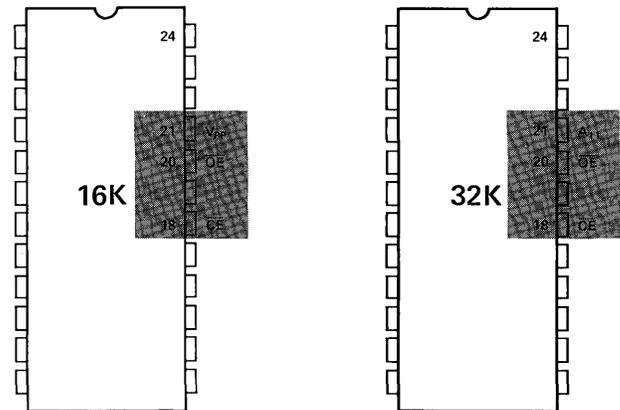


Figure 1. 16K EPROM Determines 32K ROM Pinout

SYSTEM ARCHITECTURE

As higher performance microprocessors have become available, the architecture of microprocessor systems has been evolving, again placing demands on memory. For many years, system designers have been plagued with the problem of bus contention when connecting multiple memories to a common data bus. There have been various schemes for avoiding the problem, but device manufacturers have been unable to design internal circuits that would guarantee that one memory device would be “off” the bus before another device was selected. With small memories (512x8 and 1Kx8), it has been traditional to connect all the system address lines together and utilize the difference between t_{ACC} and t_{CO} to perform a decode to select the correct device (as shown in Figure 2).

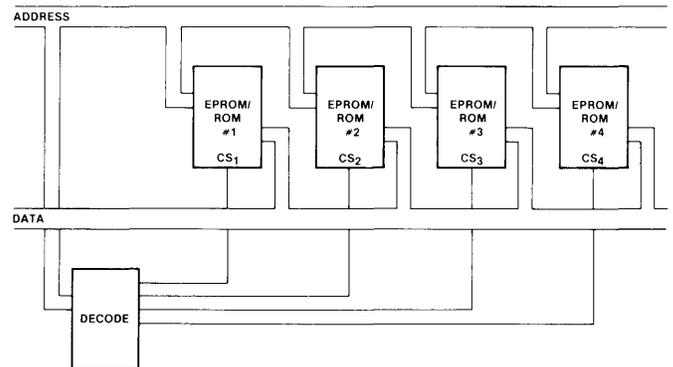


Figure 2. Single Control Line Architecture

With the 1702A, the chip select to output delay was only 100ns shorter than the address access time; or to state it another way, the t_{ACC} time was 1000ns while the t_{CO} time was 900ns. The 1702A t_{ACC} performance of 1000ns was suitable for the 4004 series microprocessors, but the 8080 processor required that the corresponding numbers be reduced to $t_{ACC} = 450ns$ and $t_{CO} = 120ns$. This allowed a substantial improvement in performance over the 4004 series of microprocessors, but placed a substantial burden on the memory. The 2708 was developed to be compatible with the 8080 both in access time and power supply requirements. A portion of each 8080 machine cycle time had to be devoted to the architecture of the system decoding scheme used. This devoted portion of the machine cycle included the time required for the system controller (8224) to perform its function before the actual decode process could begin.

Let's pause here and examine the actual decode scheme that was used so we can understand how the control functions that a memory device requires are related to system architecture.

The 2708 can be used to illustrate the problem of having a single control line. The 2708 has only one read control function, chip select (\overline{CS}), which is very fast ($t_{CO} = 120ns$) with respect to the overall access time ($t_{ACC} = 450ns$) of the 2708. It is this time difference (330ns) that is used to perform the decode function, as illustrated in Figure 3. The scheme works well and does not limit system performance, but it does lead to the possibility of bus contention.

BUS CONTENTION

There are actually two problems with the scheme described in the previous section. First, if one device in a multiple memory system has a relatively long deselect time, and a relatively fast decoder is used, it would be possible to have another device selected at the same time. If the two devices thus selected were reading opposite data; that is, device number one reading a HIGH and device number two reading a LOW, the output transistors of the two memory devices would effectively produce a short circuit, as Figure 4 illustrates. In this case, the current path is from V_{CC} on device number one to GND on device number two. This current is limited only by the "on" impedance of the MOS output transistors and can reach levels in excess of 200mA per device. If the MOS transistors have a lot of "extra" margin, the current is usually not destructive; however, an instantaneous load of 400mA can produce "glitches" on the V_{CC} supply — glitches large enough to cause standard TTL devices to drop bits or otherwise malfunction, thus causing incorrect address decode or generation.

The second problem with a single control line scheme is more subtle. As previously mentioned, there is only one control function available on the 2708 and any decoding scheme must use it out of necessity. In addition, any inadvertent changes in the state of the high order address lines that are inputs to the decoder will cause a change in

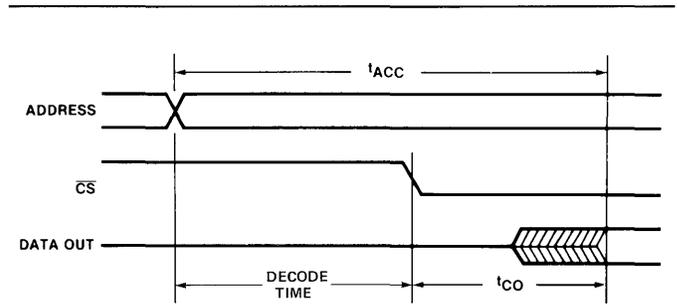


Figure 3. Single Line Control Architecture

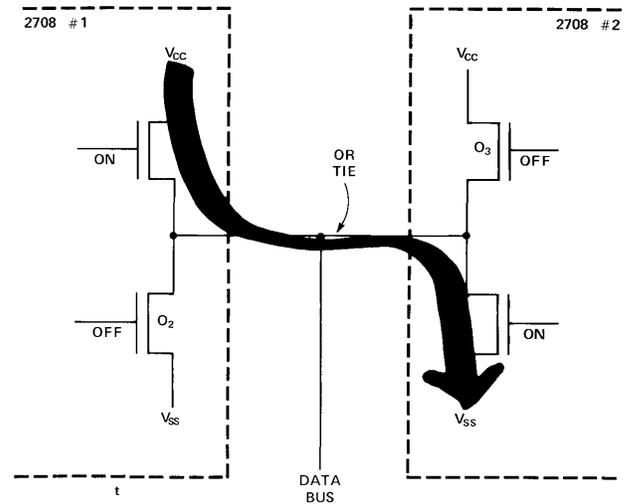


Figure 4. Results of Improper Timing when OR Tying Multiple Memories

the device that is selected. The result is the same as before — bus contention, only from a different source. The deselected device cannot get "off" the bus before the selected one is "on" the bus as the addresses rapidly change state. One approach to solving this problem would be to design (and specify as a maximum) devices with t_{DF} time less than t_{CO} time, thereby assuring that if one device is selected while another is simultaneously being deselected, there would be some small (20ns) margin. Even with this solution, the user would not be protected from devices which have very fast t_{CO} times (t_{CO} is specified as a maximum).

The only sure solution appears to be the use of an external bus driver/transceiver that has an independent enable function. Then that function, not the "device selecting function," or addresses, could control the flow of data "on" and "off" the bus, and any contention problems would be confined to a particular card or area of a large card. In fact, many systems are implemented that way — the use of bus drivers is not at all uncommon in large systems where the drive requirements of long, highly capacitive interconnecting lines must be taken into consideration — it also may be the reason why more system designers were not aware of the bus contention problem

until they took a previously large (multicard) system and, using an advanced microprocessor and higher density memory devices, combined them all on one card, thereby eliminating the requirement for the bus drivers, but experiencing the problem of bus contention as described above.

THE MICROPROCESSOR/MEMORY INTERFACE

From the foregoing discussion, it becomes clear that some new concepts, both with regard to architecture and performance are required. A new generation of two control line EPROM devices is called for with general requirements as listed below:

1. Complete ROM pin and function compatibility.
2. A power control function that allows the device to enter a low-power standby mode when deselected. This function can be used as the primary device selecting function, independent of the output control.
3. Capability to control the data "on" and "off" the system bus, independent of the device selecting function identified above.
4. Access time compatible with the high performance microprocessors that are currently available.

Now let's examine the system architecture that is required to implement the two line control and prevent bus contention. This is shown in the form of a timing diagram (Figure 5). As before, addresses are used to generate the unique device selecting function, but a separate and independent Output Enable (OE) control is now used to gate data "on" and "off" the system data bus. With this scheme, bus contention is completely eliminated as the processor determines the time during which data must be present on the bus and then releases the bus by way of the Output Enable line, thus freeing the bus for use by other devices, either memories or peripheral devices. This type of architecture can be easily accomplished if the memory devices have two control functions, and the system is implemented according to the block diagram shown in Figure 6. It differs from the previous block diagram (shown in Figure 2) in that the control bus, which is connected to all memory Output Enable pins, provides separate and independent control over the data bus. In this way, the microprocessor is always in control of the system; while in the previous system, the microprocessor passed control to the particular memory device and then waited for data to become available. Another way to look at it is, with a single control line the system is always asynchronous with respect to microprocessor/memory communications. By using two control lines, the memory is synchronized to the processor.

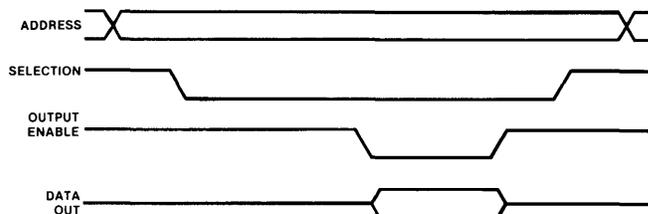


Figure 5. Two Control Line Architecture

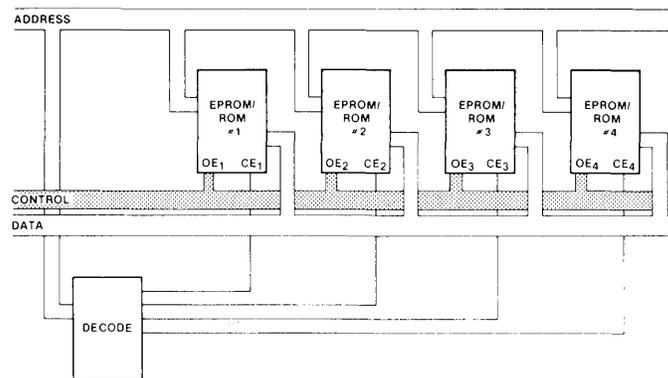


Figure 6. Two Control Line Architecture

TERMINOLOGY

Some of the terminology applied to the functions of the Intel 5 volt compatible family may be confusing or unfamiliar to many EPROM/ROM users, so the various terms are defined here. Actually, the nomenclature was developed by various standards groups and is reiterated here to avoid confusion as we begin a detailed discussion of the devices themselves.

First of all, Chip Enable (CE) must be defined, as it is the primary device selection pin. By agreed standards, that function which substantially affects power dissipation is called CE. Any memory device that has a CE function has both an active and standby power level associated with it.

Output Enable (OE) is the signal that controls the output. The fundamental purpose of OE is to provide a completely separate means of controlling the output buffer of the memory device, thereby eliminating bus contention.

Chip Select (CS) is a signal that gets logically ANDed with addresses. In a completely static device, CS must remain stable throughout the entire device cycle, and its function is equivalent to Output Enable (OE).

THE NEW INTEL FAMILY

Figure 7 shows the new Intel 5 volt compatible family of EPROMs and ROMs. In order to take advantage of the modular compatibility offered by the family, the functional compatibility of device pins 18, 19 and 21 must be understood. (Shaded area in Figure 7.)

First, we must examine the compatibility of the two oldest EPROM members of the 5 volt family — the 8K (2758) and the 16K (2716).

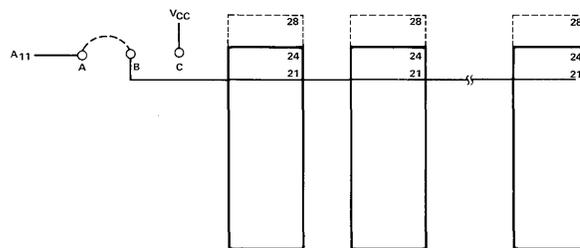
Pin 21 (V_{PP}) is normally connected to V_{CC} for read only applications of both devices, and pin 19 is either at GND (V_{IL}) for the 8K 2758 or connected to A_{10} for the 16K 2716. Further details on either of these devices can be found in Section 9 of the 1977 Edition of the Intel Memory Design Handbook, or Section 4 of the 1978 Intel Data Catalog.

The 32K (4Kx8) devices, which have identical pinouts for both the ROM and EPROM, will now be discussed. Pin 18 is \overline{CE} . Pin 19 is A_{10} , while pin 20 is \overline{OE} . As was pointed out before, Output Enable is the function which allows independent control of the data “on” and “off” the output bus. As Figure 7 indicates, V_{PP} (the programming voltage for the 2732 EPROM) is now multiplexed with \overline{OE} on pin 20. Pin 21 becomes A_{11} , which is the additional address bit that is required as the density increases from 16K to 32K.

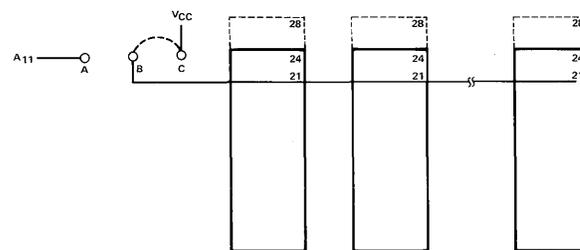
Pin 21 is the only pin that requires any special consideration when designing a system to accept the 8K, the 16K, or the 32K device. With the 8K and the 16K devices, pin 21 must be connected to V_{CC} , while with the 32K and higher density devices, it must be connected to A_{11} . This is easily accomplished by making sure the printed circuit trace links all pin 21's together as though they were an address line and allowing for a jumper that will connect pin 21 to either V_{CC} or A_{11} at the edge of the array (this technique can be seen in the “Printed Circuit Board Design” section and in Figure 8). Connecting the pin 21's together in this manner is acceptable as the read current requirement for V_{PP} is 4mA maximum per device — low enough to be handled by a signal trace, but too high for an address driver to provide directly.

The highest density member of the family is a 64K ROM which is also shown in Figure 7. In order to maintain total compatibility it is packaged in a standard 28-pin package.

It may seem as though the 28 pin package is not compatible with the rest of the family, but referring again to Figure 7, note that the lower 24 pins are identical to the 24 pin 8K, 16K and 32K devices. To allow for total compatibility within the family: printed circuit boards must be laid out to accommodate 28 pin sites; a jumper must be included to accommodate pin 21 as shown in Figure 8, and when using 64K devices, CS_2 (Pin 26) must be mask coded active high. This compatibility can also be seen graphically in Figures 9 and 10. The upper portion of the figure shows how 24 pin devices are used in the 28 pin sites. The two control lines (\overline{CE} and \overline{OE}) remain unchanged as discussed earlier, and A_{12} , the next address bit required for a 64K bit device, is connected to pin 2 of the 28 pin site. The lower portion of the figure illustrates the use of 28 pin devices. Address bit A_{12} is already connected to the right pin, and the chip selects (CS_1 and CS_2) are connected to the V_{CC} power distribution grid. This configuration would require that both CS_1 and CS_2 be coded active high.



32K Bit Density and Higher



8K and 16K Density Devices

Figure 8. Pin 21 Connections for Various Density Devices

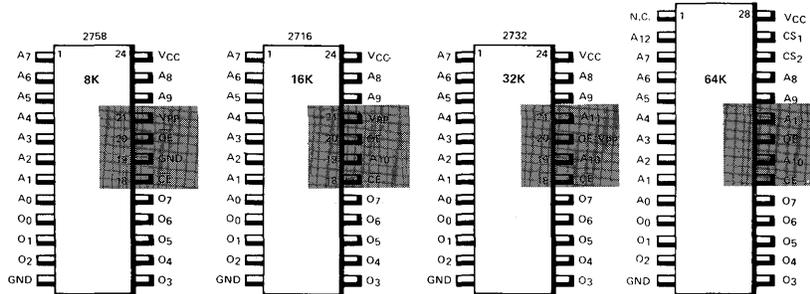
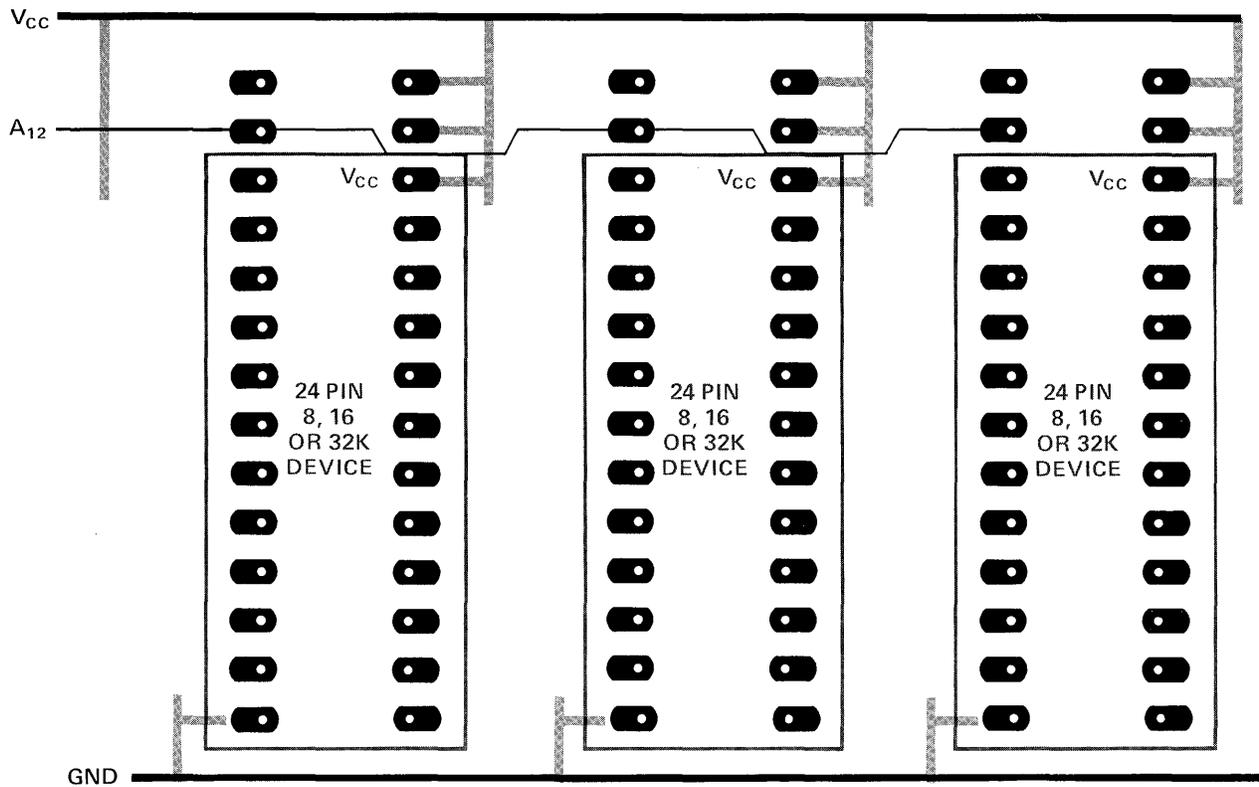
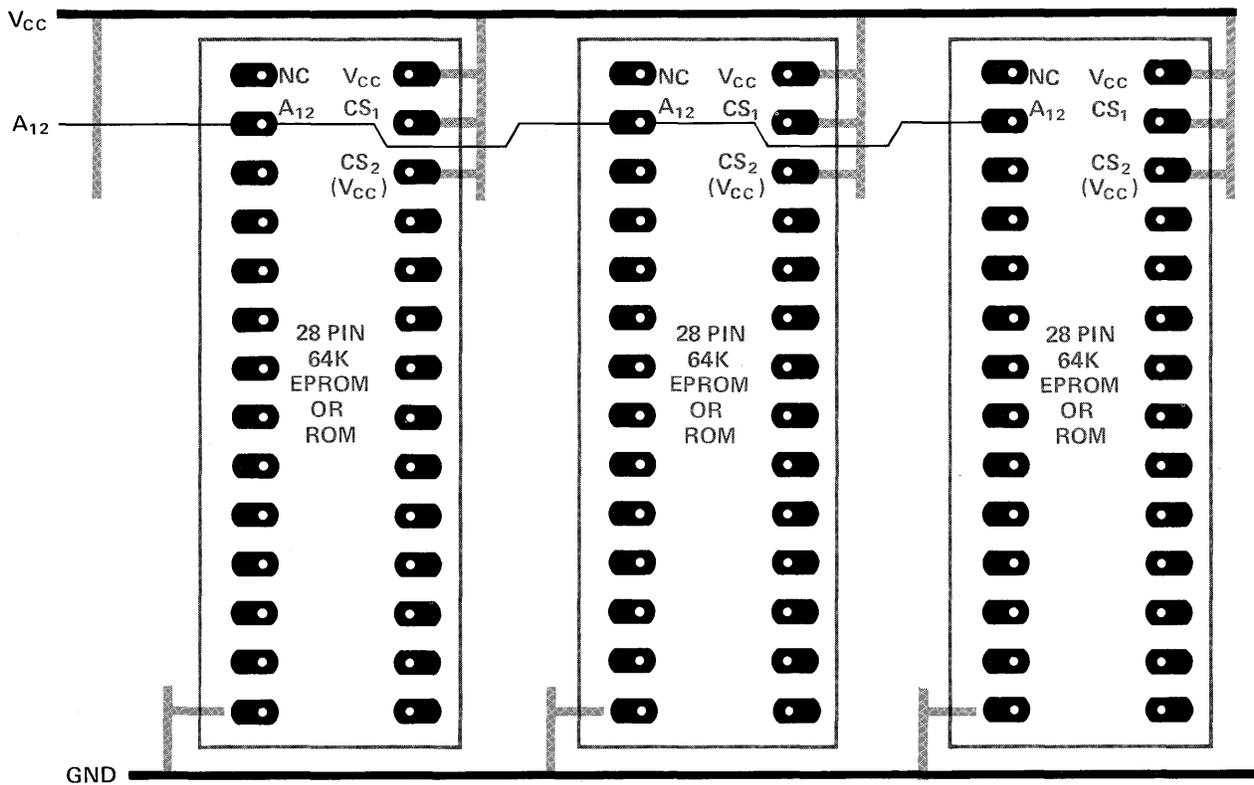


Figure 7. 5 Volt EPROM/ROM Compatible Family



24 Pin Devices and 28 Pin Sites



28 Pin Devices and 28 Pin Sites

Figure 9.

In some systems, additional logic may be used to implement a "special" decode of CS_1 to allow for ROM to overlap RAM when a system bootstrap program is being loaded; that additional logic should be implemented with CS_1 ; CS_2 should be coded active high in order to preserve total compatibility.

To summarize, the selection of a 28 pin package for 64K devices has several benefits of importance to present and future system designs:

1. Two line control philosophy (separate \overline{CE} and \overline{OE} functions) is preserved at the 64K bit level.
2. 64K EPROM compatibility is allowed for by maintaining a pin for the V_{PP} function.
3. The next generation (128K bit ROM) must be in a 28 pin package.

If CS_2 (pin 26) is mask coded to be active high and connected to V_{CC} , and the jumper provision for pin 21 is included on the card as described above, any member of the family can be plugged into the same socket — 1K, 2K, 4K or 8K bytes — without any card modification or redesign. In addition, future devices of higher density will fit in the same pinout.

PRINTED CIRCUIT BOARD DESIGN

The 2716 and the 2732 are both completely static devices that automatically enter a low power standby mode whenever \overline{CE} is high. When \overline{CE} is taken low, the device "powers up" and enters the active mode. This change from standby to active power can cause transient currents that must be suppressed by properly selected decoupling capacitors. High quality, high frequency ceramic capacitors of small physical size with low inherent inductance should be used. In addition, bulk decoupling must be provided, usually near where the power supply is connected to the array. The purpose of the bulk

decoupling is to overcome the voltage droop caused by the inductive effects of the PC board traces. Electrolytic or tantalum capacitors are suitable for bulk decoupling. The following capacitance values and locations are recommended for the 16K and 32K:

1. A $0.1\mu\text{F}$ ceramic capacitor between V_{CC} and GND at every other device.
2. A $4.7\mu\text{F}$ electrolytic capacitor between V_{CC} and GND for each eight devices.

A printed circuit board layout for a total array of 16 devices is shown in Figure 10. This printed circuit layout incorporates a power supply distribution system such that the power supply and ground traces on the PC board are gridded both vertically and horizontally at each memory device; this technique minimizes the power distribution system impedance and enhances the effect of the decoupling capacitors. Provisions are included for all address inputs, output enable inputs, data outputs and decoded chip enable inputs. The $0.1\mu\text{F}$ capacitors referred to above are included for every other device (indicated by the legend C2) while the bulk decoupling capacitor is shown at the upper left-hand corner (indicated by the legend C1). The layout consists of four rows of four 28-pin device sites each and embodies all of the concepts explained above. Note that pins 28, 27 and 26 are all connected to V_{CC} . This requires that when ordering mask programmed 64K ROMs, the order must specify that CS_1 and CS_2 be coded active HIGH. The single jumper provision discussed in the previous section is also included at the upper lefthand corner of the array (indicated by A, B, and C). Pad B is connected to pin 21 of all devices in the array; pad A should be connected to the A_{11} address driver and pad C is connected to V_{CC} . For use with 32K bit or larger devices, a jumper must be installed between pads A and B; for use with the 2716 (16K) or the 2758 (8K), the jumper must be installed between pads B and C.

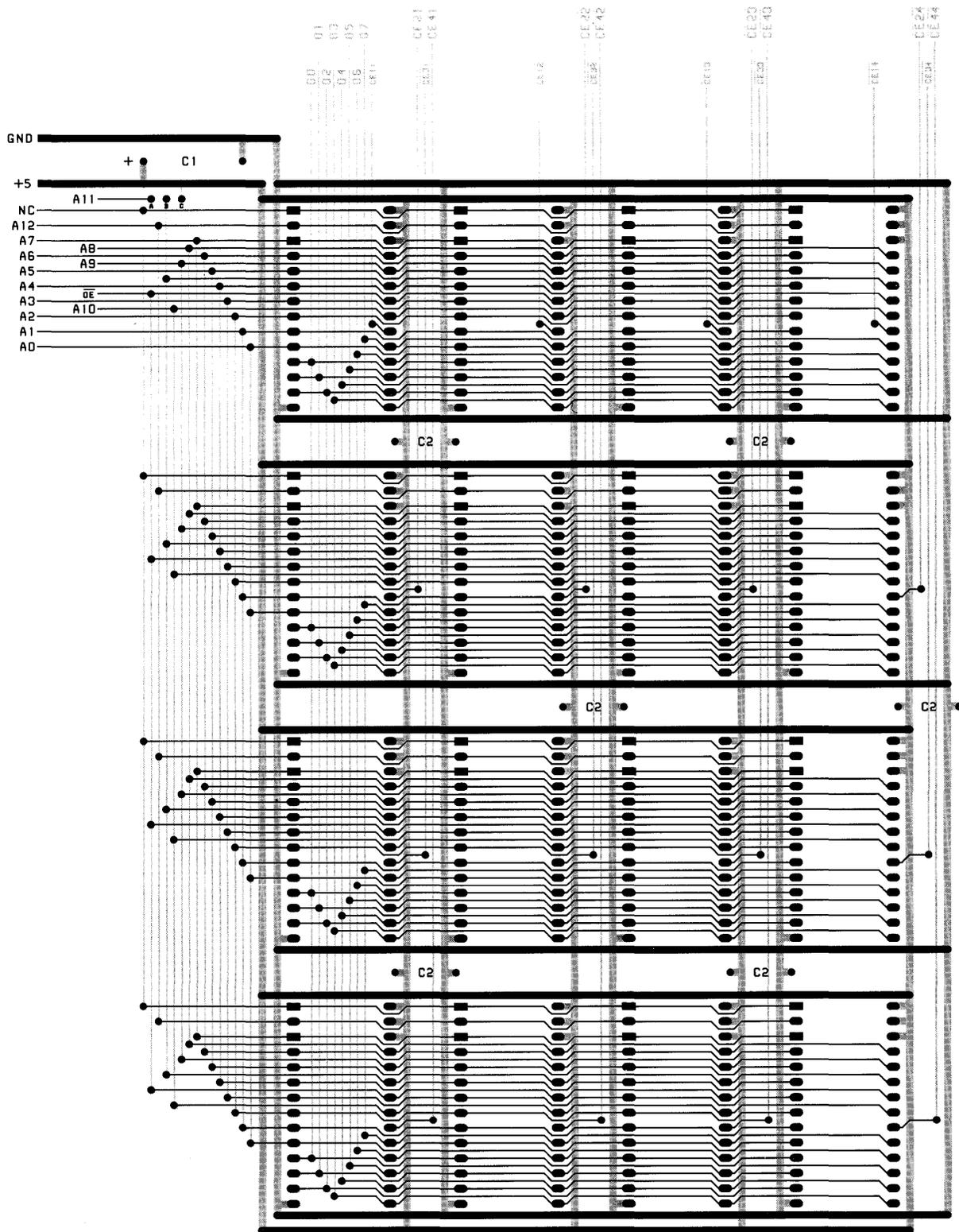


Figure 10.



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Printed in U.S.A./G44/0579/10K DA BL