

Memory Address Decoding

The processor can usually address a memory space that is *much larger* than the memory space covered by an individual memory chip.

In order to splice a memory device into the address space of the processor, decoding is necessary.

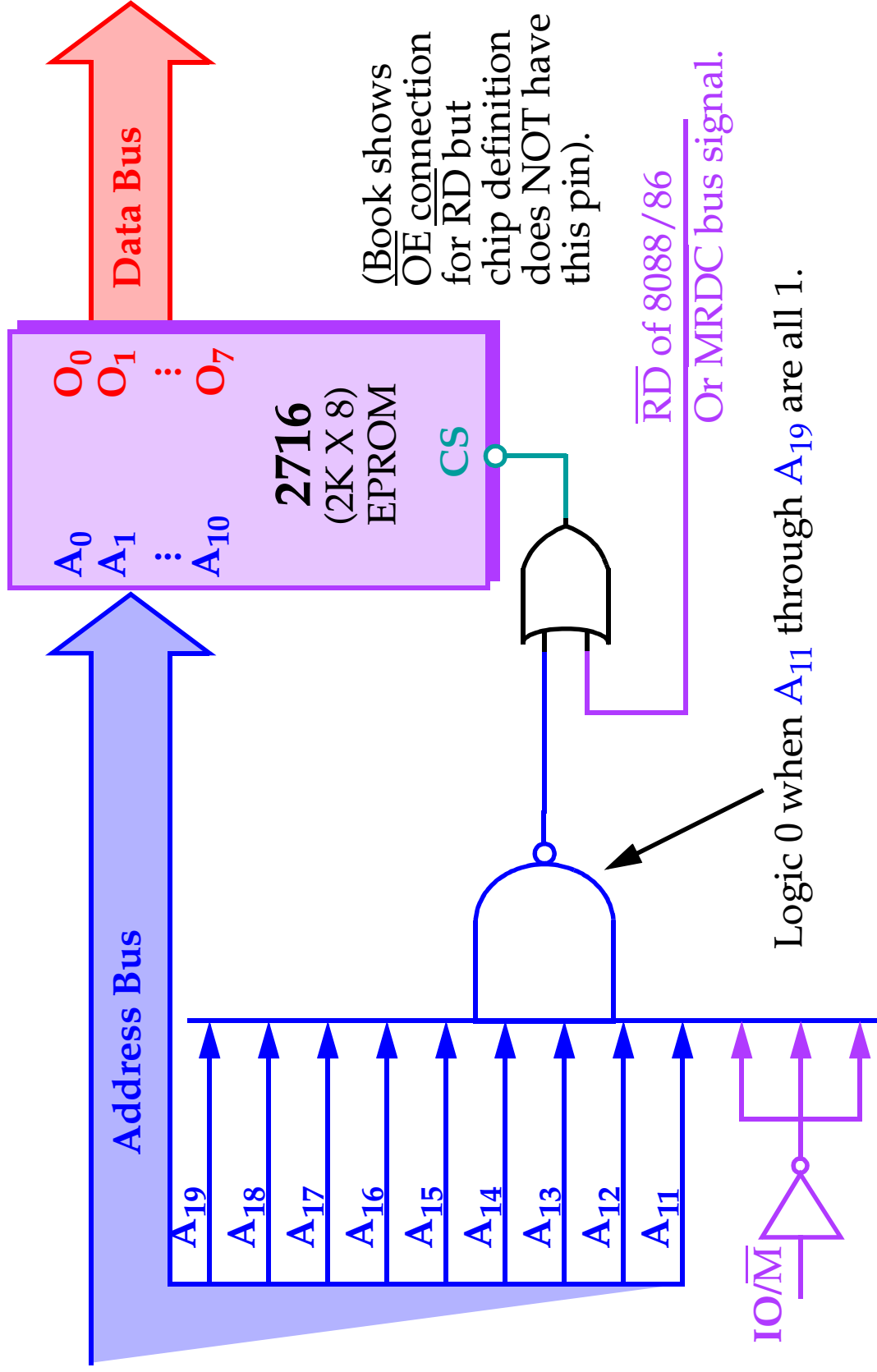
For example, the 8088 issues *20-bit* addresses for a total of **1MB** of memory address space.

However, the BIOS on a 2716 EPROM has only 2KB of memory and *11* address pins.

A decoder can be used to decode the additional 9 address pins and allow the EPROM to be placed in **any** 2KB section of the 1MB address space.

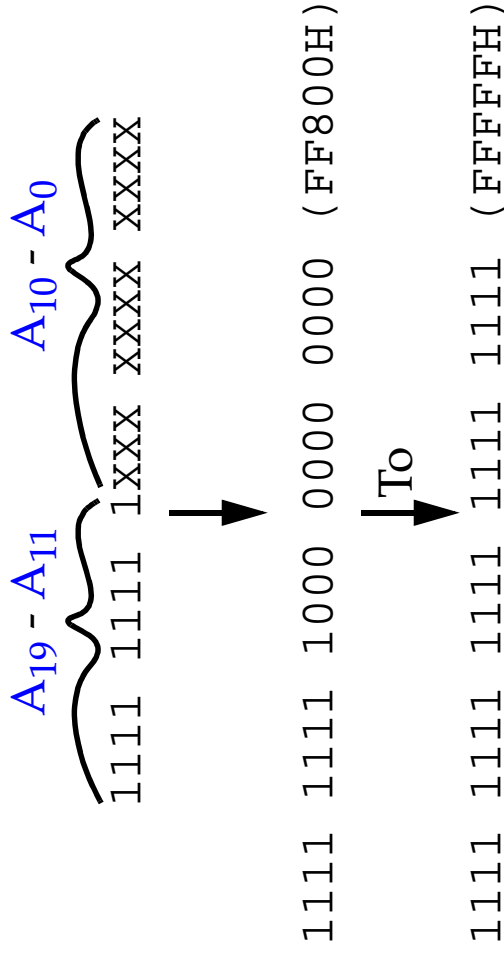


Memory Address Decoding



Memory Address Decoding

To determine the address range that a device is mapped into:



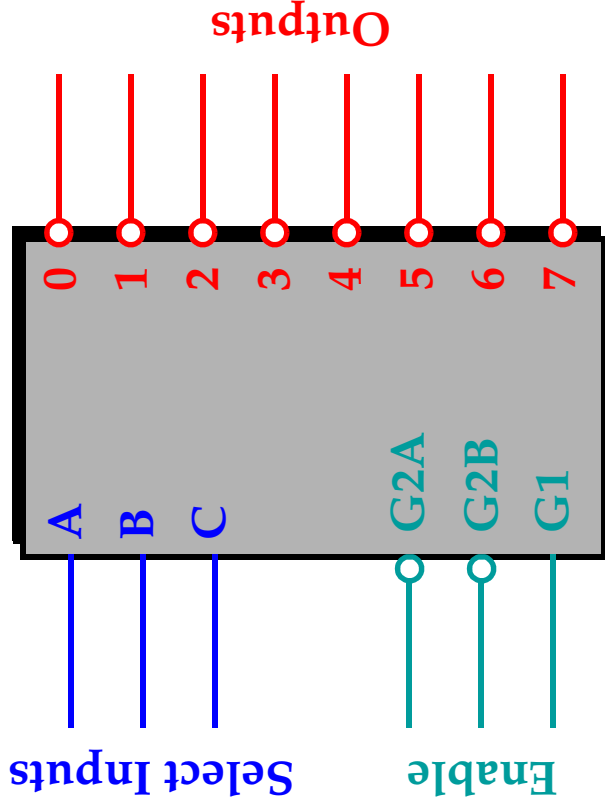
This 2KB memory segment maps into the **reset location** of the 8086/8088 (FFFFFF0H).

NAND gate decoders are not often used.

Rather the 3-to-8 Line Decoder (74LS138) is more common.

Memory Address Decoding

The 3-to-8 Line Decoder (74LS138)



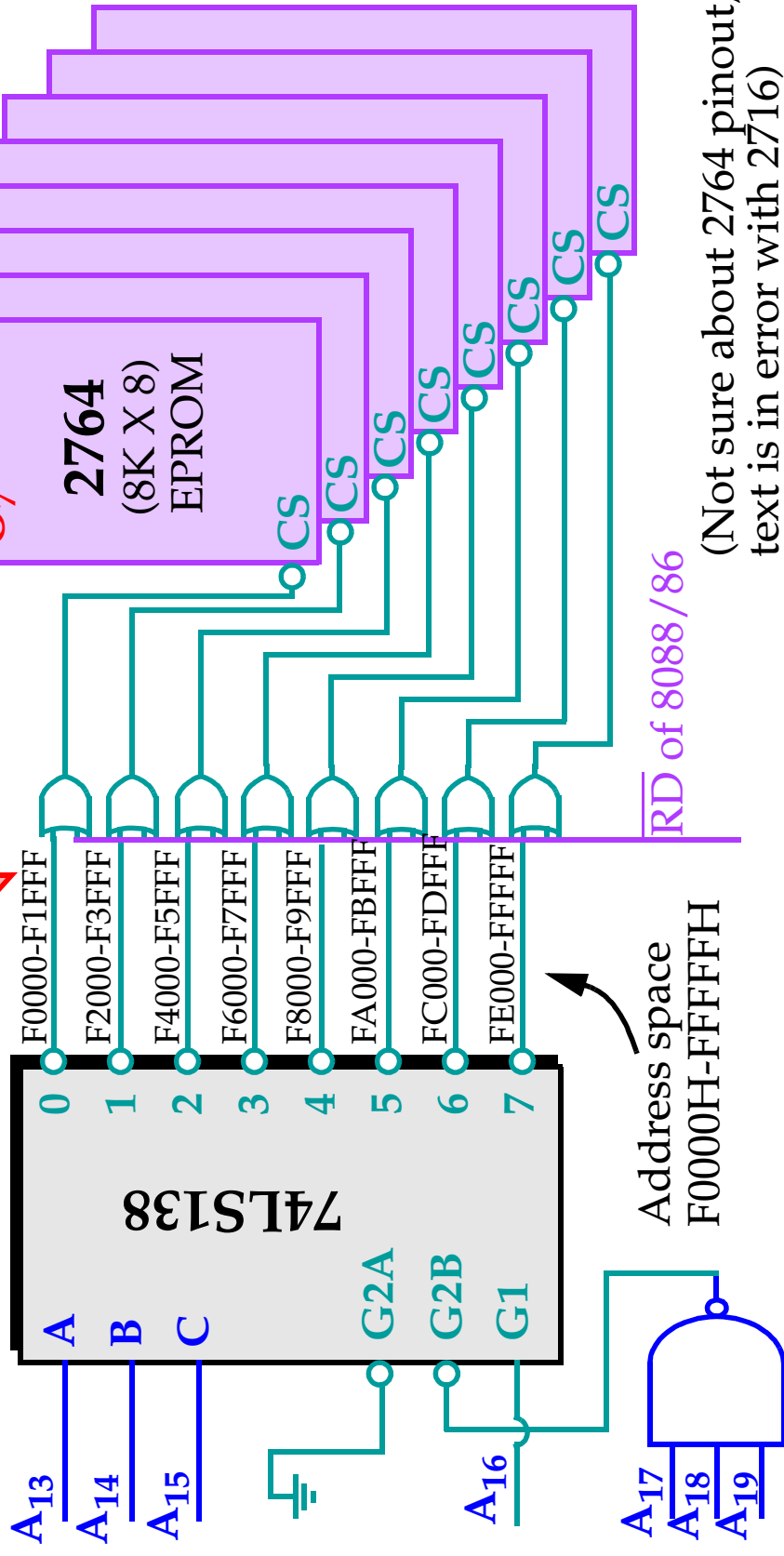
Enable			Inputs			Output							
G2A	G2B	G1	C	B	A	0	1	2	3	4	5	6	7
1	X	X	X	X	X	1	1	1	1	1	1	1	1
X	1	X	X	X	X	1	1	1	1	1	1	1	1
X	X	0	X	X	X	1	1	1	1	1	1	1	1
0	0	1	0	0	0	0	1	1	1	1	1	1	1
0	0	1	0	0	1	1	0	1	1	1	1	1	1
0	0	1	0	1	0	1	1	0	1	1	1	1	1
0	0	1	0	1	1	1	1	1	0	1	1	1	1
0	0	1	1	0	0	1	1	1	1	0	1	1	1
0	0	1	1	0	1	1	1	1	1	1	0	1	1
0	0	1	1	1	0	1	1	1	1	1	1	0	1
0	0	1	1	1	1	1	1	1	1	1	1	1	0

Note that all *three* Enables (G2A, G2B, and G1) must be active, e.g. low, low and high, respectively.

Each output of the decoder can be attached to an 2764 EPROM (8K X 8).

Memory Address Decoding

A₁₃ through A₁₅ select a 2764
A₁₆ through A₁₉ enable the decoder



(Not sure about 2764 pinout, text is in error with 2716)

The EPROMs cover a 64KB section of memory.

Memory Address Decoding

Yet a third possibility is a **PLD** (Programmable Logic Device).

PLDs come in three varieties:

- *PLA* (Programmable Logic Array)
- *PAL* (Programmable Array Logic)
- *GAL* (Gated Array Logic)

PLDs have been around since the mid-1970s but have only recently appeared in memory systems (PALs have replaced PROM address decoders).

PALs and PLAs are **fuse-programmed** (like the PROM).

Some are erasable (like the EPROM).

A PAL example (16L8) is shown in the text and is commonly used to decode the memory address, particularly for 32-bit addresses generated by the 80386DX and above.

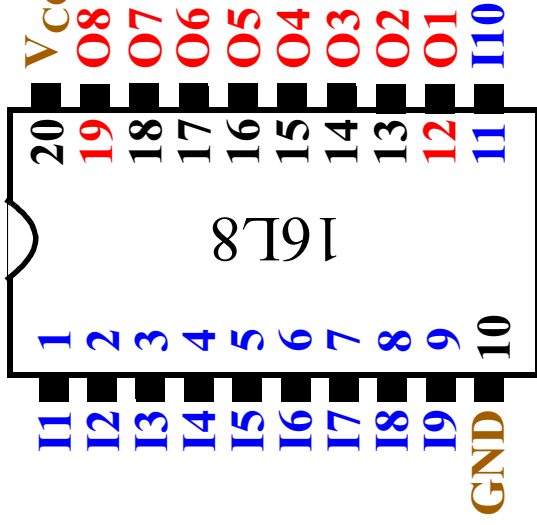
Memory Address Decoding

AMD 16L8 PAL decoder.

It has 10 fixed inputs (Pins 1-9, 11), two fixed outputs (Pins 12 and 19) and 6 pins that can be either (Pins 13-18).

Programmed to decode address lines $A_{19} - A_{13}$ onto 8 outputs.

;pins	1	2	3	4	5	6	7	8	9	10
	A19	A18	A17	A16	A15	A14	A13	NC	NC	GND
;pins	11	12	13	14	15	16	17	18	19	20
	NC	O8	O7	O6	O5	O4	O3	O2	O1	VCC



Equations:

$$\begin{aligned}
 /O1 &= A_{19} * A_{18} * A_{17} * A_{16} * /A_{15} * /A_{14} * /A_{13} \\
 /O2 &= A_{19} * A_{18} * A_{17} * A_{16} * /A_{15} * /A_{14} * A_{13} \\
 /O3 &= A_{19} * A_{18} * A_{17} * A_{16} * /A_{15} * A_{14} * /A_{13} \\
 /O4 &= A_{19} * A_{18} * A_{17} * A_{16} * /A_{15} * A_{14} * A_{13} \\
 /O5 &= A_{19} * A_{18} * A_{17} * A_{16} * A_{15} * /A_{14} * /A_{13} \\
 /O6 &= A_{19} * A_{18} * A_{17} * A_{16} * A_{15} * /A_{14} * A_{13} \\
 /O7 &= A_{19} * A_{18} * A_{17} * A_{16} * A_{15} * A_{14} * /A_{13} \\
 /O8 &= A_{19} * A_{18} * A_{17} * A_{16} * A_{15} * A_{14} * A_{13}
 \end{aligned}$$

AND/NOR device with logic expressions (outputs) with up to 16

ANDed inputs and 7 ORed product terms.

8088 and 80188 (8-bit) Memory Interface

The memory systems “sees” the 8088 as a device with:

- 20 address connections (A19 to A0).
- 8 data bus connections (AD7 to AD0).
- 3 control signals, IO/M, RD, and WR.

We’ll look at interfacing the 8088 with:

- 32K of EPROM (at addresses F8000H through FFFFFH).
- 512K of SRAM (at addresses 00000H through 7FFFFH).

The EPROM interface uses a 74LS138 (3-to-8 line decoder) plus 8 2732 (4K X 8) EPROMs.

The EPROM will also require the generation of a wait state.

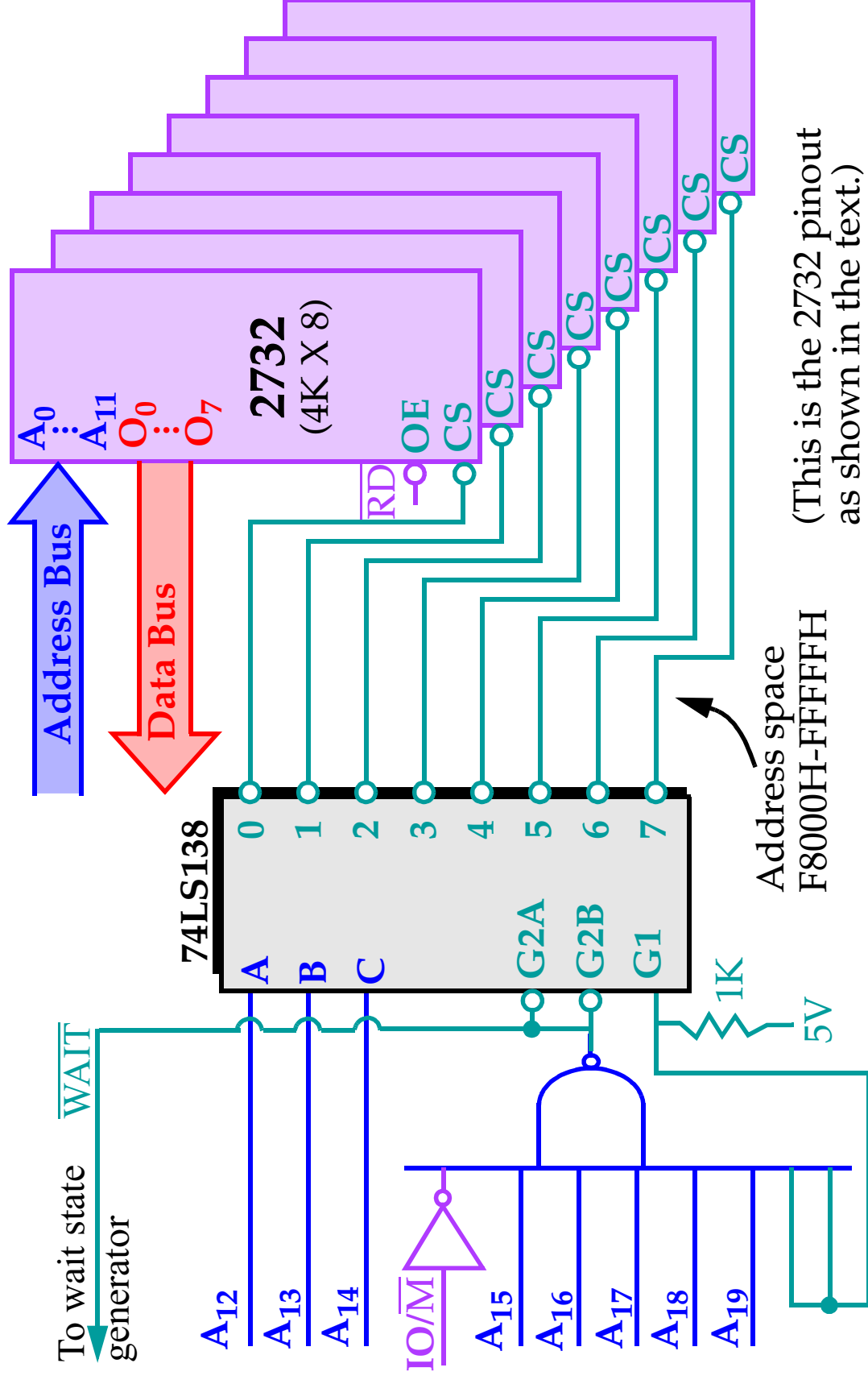
The EPROM has an access time of $450ns$.

The 74LS138 requires $12ns$ to decode.

The 8088 runs at 5MHz and only allows $460ns$ for memory to access data.

A wait state adds $200ns$ of additional time.

8088 and 80188 (8-bit) EPROM Memory Interface

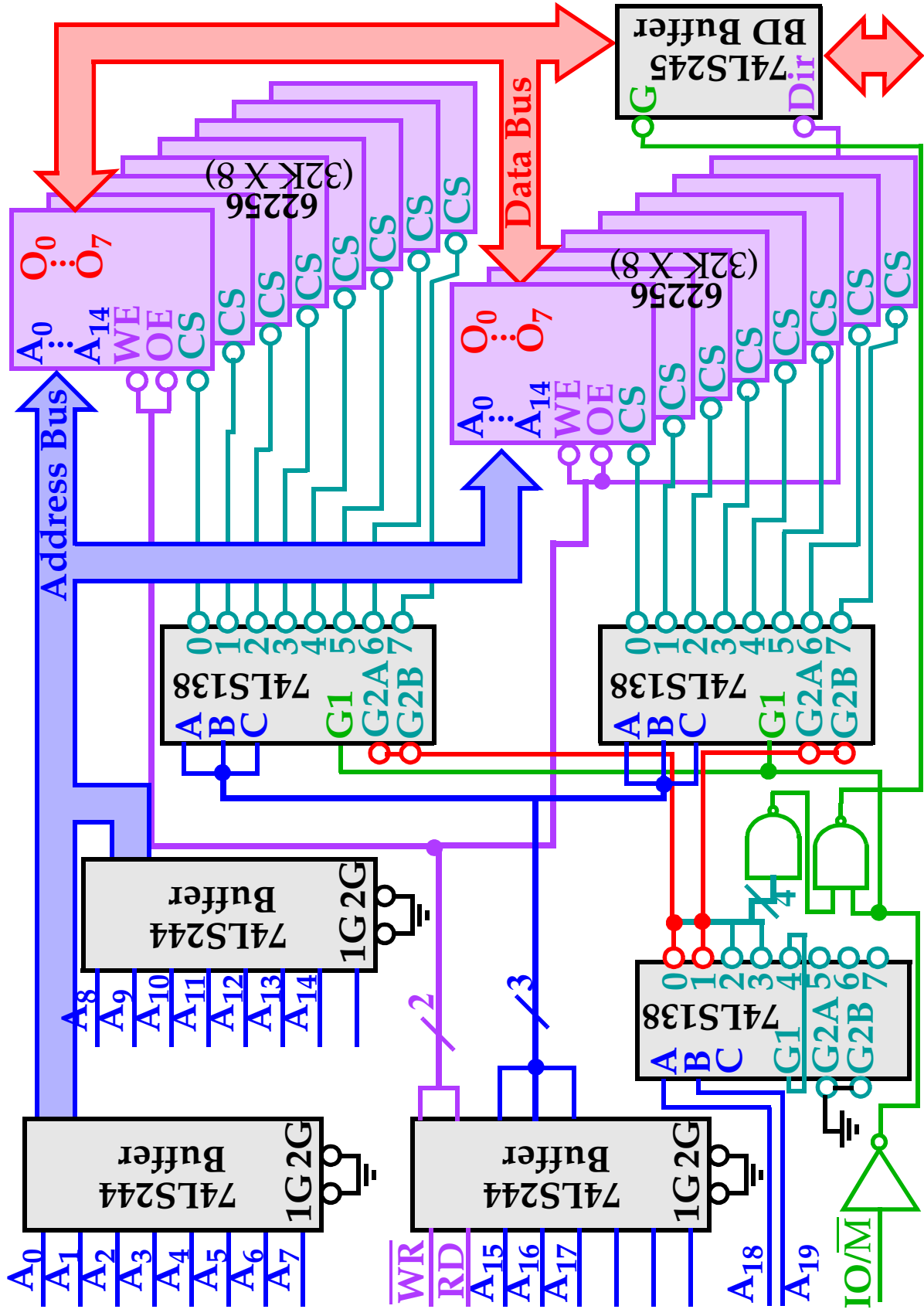


(This is the 2732 pinout as shown in the text.)

The 8088 cold starts execution at $FFFF0H$. JMP to $F8000H$ occurs here.



8088 and 80188 (8-bit) RAM Memory Interface



8088 and 80188 (8-bit) RAM Memory Interface

The 16 62256s on the previous slide are actually SRAMs.

Access times are on order of $10ns$.

Flash memory can also be interfaced to the 8088 (see text).

However, the write time ($400ms$!) is too slow to be used as RAM (as shown in the text).

Parity Checking:

Parity checking is used to detect single bit errors in the memory.

The current trend is away from parity checking.

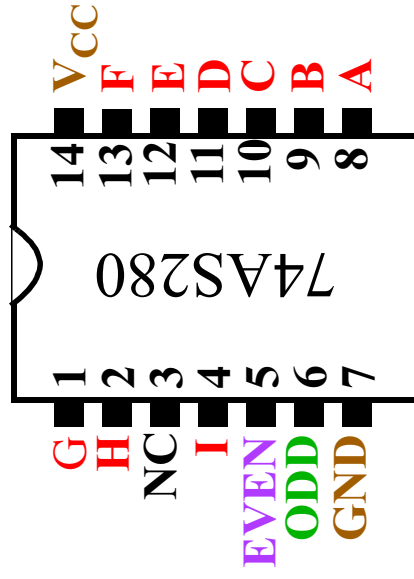
Parity checking adds 1 bit for every 8 data bits.

- For *EVEN* parity, the 9th bit is set to yield an even number of 1's in all 9 bits.
- For *ODD* parity, the 9th bit is set to make this number odd.

For 72-pin SIMMs, the number of data bits is $32 + 4 = 36$ (4 parity bits).

Parity for Memory Error Detection

74AS280 Parity Generator / Checker



9-bit parity generator/checker

This circuit generates *EVEN* or *ODD* parity for the 9-bit number placed on its inputs.

Typically, for generation, the 9th input bit is set to 0.

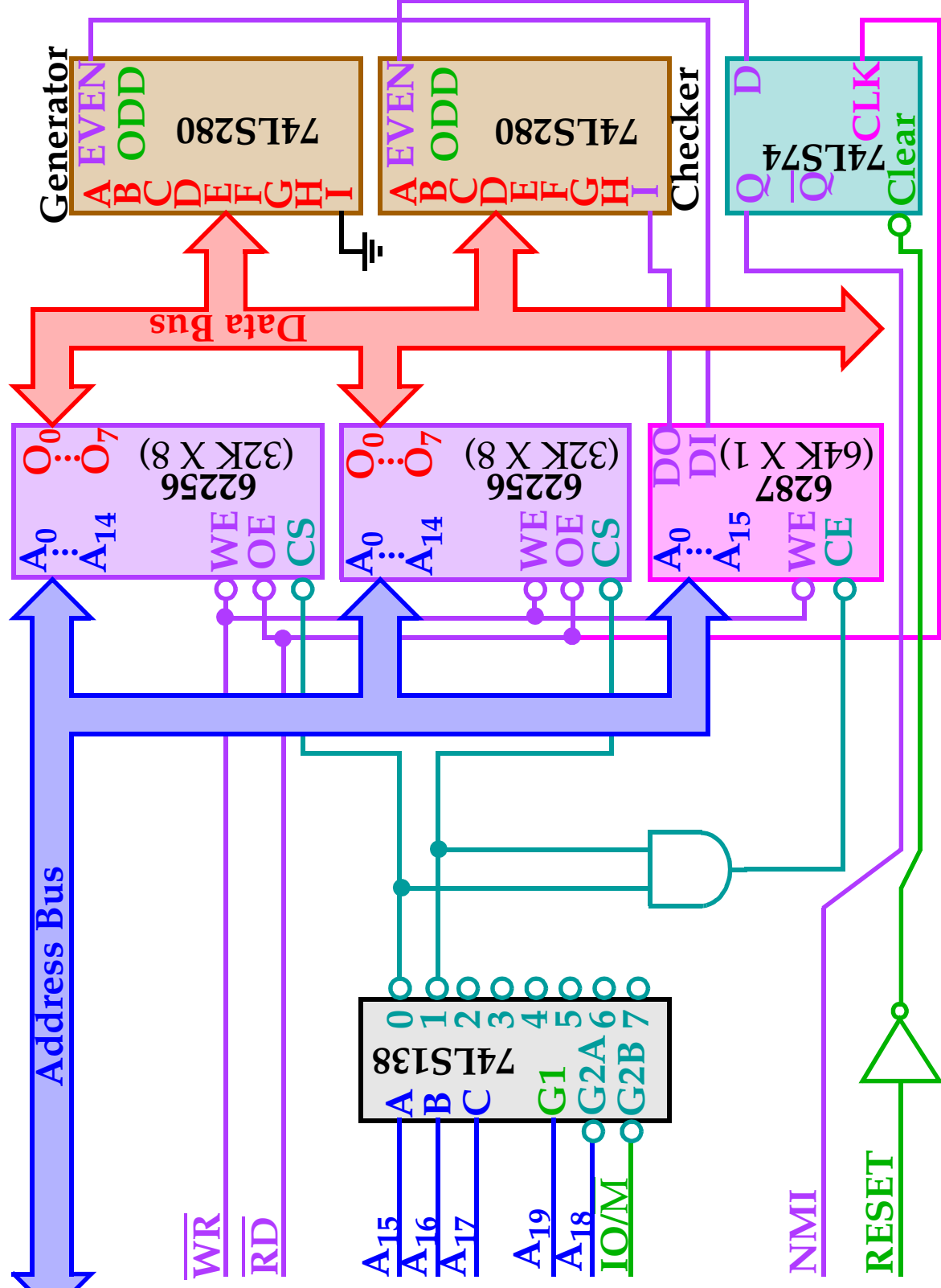
This circuit also checks *EVEN* or *ODD* parity for the 9-bit number.

In this case, the **9th** input bit is connected to the **9th** bit of memory.

For example, if the original byte has an even # of 1's (with **9th** bit at GND), the parity bit is set to 1 (from the *EVEN* output).

If the *EVEN* output goes high during the check, then an error occurred.

Number of inputs A thru I that are HIGH	Outputs EVEN ODD
0, 2, 4, 6, 8	H L
1, 3, 5, 7, 9	L H

Parity for Memory Error Detection

Error Detection

This parity scheme can only detect a single bit error.

- Block-Check Character (**BCC**) or Checksum.

Can detect *multiple bit* errors.

This is simply the **two's complement sum** (the negative of the sum) of the sequence of bytes.

No error occurred if adding the data values and the checksum produces a 0.

For example:

Given 4 hex data bytes: 10, 23, 45, 04

Compute the sum:

$$\begin{array}{r} 10 \\ 23 \\ 45 \\ 04 \\ \hline 7C \end{array}$$

Invert and add 1
to get checksum byte:

$$\begin{array}{r} \overline{0111\ 1100} + 1 \\ 1000\ 0011 + 1 \\ \hline 1000\ 0100 = 84H \end{array}$$

Check is made by adding
and checking for 00
(discard the carry):

$$\begin{array}{r} 10 \\ 23 \\ 45 \\ 04 \\ 84 \\ \hline 100 \end{array}$$

This is not fool proof.

If 45 changes to 44 *AND* 04 changes to 05, the error is missed.



Error Detection

- Cyclic Redundancy Check (CRC).

Commonly used to check data transfers in hardware such as harddrives.
Treats data as a stream of serial data n -bits long.

The bits are treated as coefficients of a **characteristic polynomial**,

$M(X)$ of the form:

$$M(X) = b_n + b_{n-1}X + b_{n-2}X^2 + \dots + b_1X^{n-1} + b_0X^n$$

where b_0 is the least significant bit while b_n is the most significant bit.

For the 16-bit data stream: 26F0H = 0010 0110 1111 0000

$$M(X) = 0 + 0X^1 + 1X^2 + 0X^3 + 0X^4 + 1X^5 + 1X^6 + 0X^7 + 1X^8 + 1X^9 + 1X^{10} + 1X^{11} + 0X^{12} + 0X^{13} + 0X^{14} + 0X^{15}$$

$$M(X) = 1X^2 + 1X^5 + 1X^6 + 1X^8 + 1X^9 + 1X^{10} + 1X^{11}$$

Error Detection

- Cyclic Redundancy Check (**CRC**) (cont.)

The **CRC** is found by applying the following equation.

$$CRC = \frac{M(X)X^n}{G(X)} = Q(X) + R(X)$$

$Q(X)$ is the quotient
 $R(X)$ is the remainder

$G(X)$ is the called the *generator polynomial* and has special properties.

A commonly used polynomial is:

$$G(X) = X^{16} + X^{15} + X^2 + 1$$

The remainder $R(X)$ is **appended** to the data block.

When the **CRC** and $R(X)$ is computed by the receiver, $R(X)$ should be zero.

Since $G(X)$ is of power 16, the remainder, $R(X)$, cannot be of order higher than 15.

Therefore, no more than 2 bytes are needed independent of the data block size.

Error Detection

- Cyclic Redundancy Check (CRC)(cont.)

$$\frac{M(X)X^{16}}{G(X)} = \frac{X^{27} + X^{26} + X^{25} + X^{24} + X^{22} + X^{21} + X^{18}}{X^{16} + X^{15} + X^2 + 1}$$

$$\frac{X^{11} + X^9 + X^6 + X^2 + X + 1}{X^{16} + X^{15} + X^2 + 1}$$

$$X^{16} + X^{15} + X^2 + 1 \left[\begin{array}{l} X^{27} + X^{26} + X^{25} + X^{24} + X^{22} + X^{21} + X^{18} \\ X^{27} + X^{26} \end{array} \right. +$$

$$X^{13} + X^{11}$$

$$X^{25} + X^{24} + X^{22} + X^{21} + X^{18} + X^{13} + X^{11}$$

$$X^{25} + X^{24} + X^{11} + X^9$$

$$X^{22} + X^{21} + X^{18} + X^{13} + X^9$$

$$X^{22} + X^{21} + X^8 + X^6$$

$$X^{18} + X^{13} + X^9 + X^8 + X^6$$

$$X^{18} + X^{17} + X^4 + X^2$$

$$X^{17} + X^{13} + X^9 + X^8 + X^6 + X^4 + X^2$$

$$X^{17} + X^{16} + X^3 + X$$

...

Final Solution is:

$$R(X) = X^{15} + X^{13} + X^9 + X^8 + X^6 + X^4 + X^3 + X + 1$$

Value appended is the reverse coefficient value 1101 1010 1100 0101 = DAC5H



Error Correction

Parity, BCC and CRC are only mechanisms for error detection.

The system is halted if an error is found in memory.

Error *correction* is starting to show up in new systems.

SDRAM has ECC (Error Correction Code).

Correction will allow the system can continue operating.

If *two* errors occur, they can be *detected* but not *corrected*.

Error correction will of course cost more in terms of extra bits.

Error correction is based on **Hamming Codes**.

There is lots of theory here but our focus will be on implementation.

The objective is to correct any single bit errors in an 8-bit data byte.

The data bits of the byte are labeled $X_3, X_5, X_6, X_7, X_9, X_{10}, X_{11}$ and X_{12} .

The parity bits are labeled P_1, P_2, P_4 and P_8 .

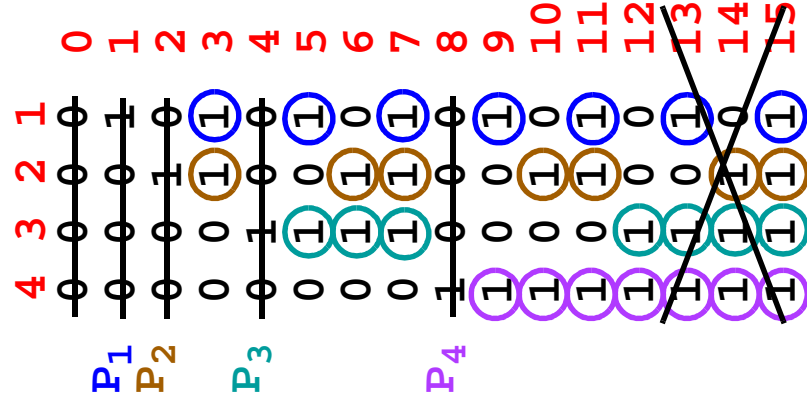
In other words, we need 4 parity bits to correct single bit errors.

Note that the parity bits are at bit positions that are *powers of 2*.

Error Correction

Hamming Codes (cont).

P1 is generated by computing the parity of $X_3, X_5, X_7, X_9, X_{11}, X_{13}, X_{15}$.
 These numbers have a 1 in bit position 1 of the subscript in binary.



P₁ is assigned even parity using $X_3, X_5, X_7, X_9, X_{11}, X_{13}, X_{15}$

P₂ is assigned even parity using $X_3, X_6, X_7, X_{10}, X_{11}, X_{14}, X_{15}$

P₃ is assigned even parity using $X_5, X_6, X_7, X_{12}, X_{13}, X_{14}, X_{15}$

P₄ is assigned even parity using $X_9, X_{10}, X_{11}, X_{12}, X_{13}, X_{14}, X_{15}$

Note that each data bit is used in the parity computation of at least 2 P bits.

Given data byte:
11010010

P₁ uses blue bits:

1 2 1 1 1 0 9 7 6 5 3
1 1 0 1 0 0 1 0

P₁ even parity is 1.

P₂ uses brown bits:

1 2 1 1 1 0 9 7 6 5 3
1 1 0 1 0 1 0 0 1 0

P₂ even parity is 1.

P₃ uses cyan bits:

1 1 0 1 0 0 1 0
P₃ even parity is 0.

P₄ uses purple bits:

1 1 0 1 0 0 1 0
P₄ even parity is 1.

Not used since we are correcting byte data.



Error Correction

Hamming Codes (cont).

Parity encoded data:

110110010011

If X_{10} flips from 0 \rightarrow 1, then the check gives the location of the bit error as:

P	1	2	1	1	0	9	7	6	5	3
1	1	1	1	1	0	1	0	0	1	0
1	1	1	1	1	0	0	0	0	1	0
0	1	1	1	1	0	0	0	1	1	0
1	1	1	1	1	1	0	0	0	1	0

P_1 even parity is 0.

P_2 even parity is now 1.

P_3 even parity is 0.

P_4 even parity is now 1.

Since these are NOT 0,
there was an error.

The position of the bit flip is given by:

$P_4P_3P_2P_1$ is 1010 or 10 decimal.

Flipped



Parity for Memory Error Correction

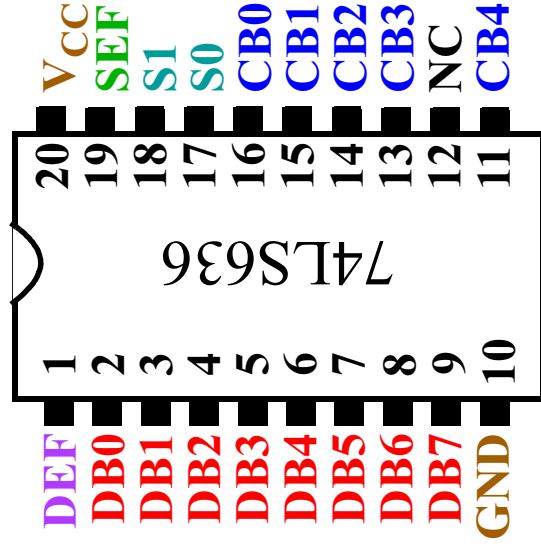
The 74LS636 corrects errors by storing 5 parity bits with each byte of data.

The pinout consists of:

- 8 data I/O pins
- 5 check bit I/O pins
- 2 control pins
- 2 error outputs

Single error flag (**SEF**)

Double error flag (**DEF**).



See the text for an example of its use in a circuit.