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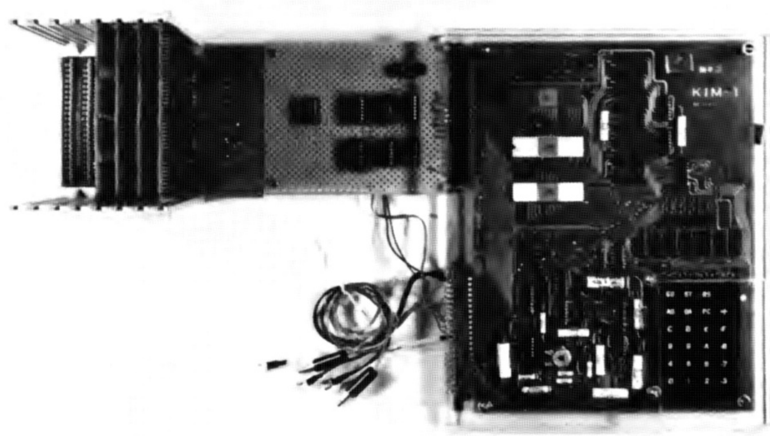
A Sensible Expansion: Atwood Memory for your KIM

There is a variety of techniques—commercial and home-brew—for KIM memory expansion. Use of Atwood boards ranks among the lower-cost methods.



KIM-1, interface/decoding circuit and Atwood Enterprises motherboard with 16K of memory.

An inexpensive way to expand the memory of a KIM-1 is to use the 4K memory cards made by Kathryn Atwood Enterprises. A single 4K card costs about $90, fully assembled. The cost of a 16K expansion for the KIM is under $400, including the cost of interfacing, connectors and mounting requirements.

Atwood's memory board comes fully buffered with CMOS on the address lines and Tri-state buffer drivers on the data lines. On-board decoding of the address lines is also provided. The board is not designed for S-100 bus operation; thus the KIM does not require additional circuitry for S-100 bus operation. Documentation includes an interconnection diagram, application notes and parts layout.

A motherboard, available for the memory card, is supplied free with the purchase of four memory cards. The motherboard construction and the bus used enable the memory card to be inserted in either direction without causing damage to the memory board. No connector is provided for the motherboard so you should purchase a connector, depending on your use of the KIM. I simply soldered directly to the motherboard, which worked, but made disconnecting the memory unit from the KIM slightly difficult.

The 4K Board

A functional schematic, provided in the interconnection diagram, is shown in Fig. 1. The data bus buffers are 8T26A and the address buffers are CMOS 4050. A 74LS138 is used to select each of the 1K banks of memory chips.

Basic operation of the memory card requires three steps: (1) connection of the 12 least significant address lines; (2) connection of the eight data lines; (3) application of the proper control signals. The control signals are defined in the Application Notes and are labeled Board Select, Output Enable and Read/Write.

Board Select is an enable signal that must be provided by some kind of decoder circuitry, depending upon where you choose to locate it in KIM memory allocation. The Board Select signal enables a 74LS138 on the expansion board, which determines the memory chips that will be enabled. If the Board Select is low, the memories will not be enabled, and you will not be able to read or write from them.

The Output Enable signal determines the direction of data through the Tri-state buffers. The Output Enable is a logical AND with the Board Select signal to determine data direction. If either signal is low, the buffers will be in a write state and appear as a high impedance to the microprocessor.

Only when both signals are high will you be able to drive the data bus from the memory (i.e., read from memory). When the Board Select is high, enabling the memory, and Output Enable is low, you will be able to write from the data bus to memory. Since the KIM R/W is a high read and a low write signal, it

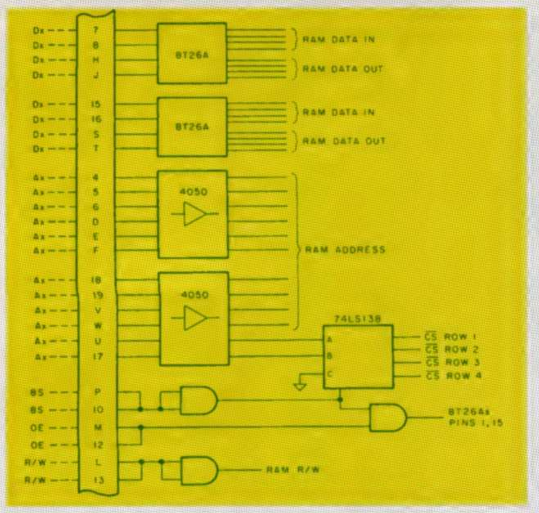
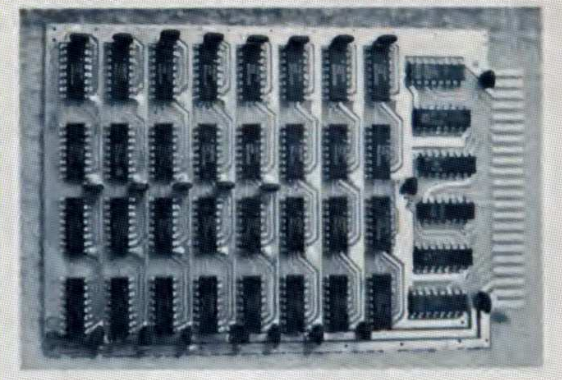


Fig. 1. Functional schematic of memory board.



The assembled Atwood 4K board.

can be used as the Output Enable signal for the expansion board.

The Read/Write signal indicates to the memory chips whether to read or write data. According to the Application Notes, the line should remain high until the address has been present at the RAMs for a minimum of 170 ns and should return high 40 ns before the data becomes invalid. The RAM R/W signal on the KIM meets those criteria and can be used for this signal. Pages 17, 18 and 19 of the *KIM Hardware Manual* show that the address will be valid for approximately 400 ns before RAM R/W goes low; the RAM R/W returns high about 30 ns before data becomes invalid.

Memory Decoding

If you wish to expand your KIM by only 4K, the job is simple. As seen in Fig. 2, the main problem of a 4K expansion is with the interconnections: the connection of the address and data lines. The Output Enable and Read/Write of the memory card are connected to the KIM R/W and the RAM R/W, respectively. The Board Select signal is generated by "wire-ORing" K1, K2, K3 and K4 on the KIM and then inverting this signal for the memory card.

Expanding the KIM above the 8K that is already decoded on the KIM causes two problems: the need for additional decoding and vector management for $\overline{NMI}$, $\overline{IRQ}$ and $\overline{RST}$.

Page 75 of the *KIM User's Manual* shows that whenever an $\overline{RST}$ (for example) is activated, the addresses FFFC, FFFD are placed on the address bus by the 6502, and the data fetched from these locations is loaded in the program counter. The basic KIM-1 does not decode the three highest address bits so that FFFC, FFFD will be read as 1FFC, 1FFD, which places you in the KIM monitor program. Whenever the KIM is expanded above the lowest 8K of memory, it becomes necessary to decode the three highest address lines.

Now when an $\overline{RST}$ occurs, U4 on the KIM will be deselected and K7 will not be activated to place you in the KIM monitor program. The solution to this problem is to generate a special signal whenever an interrupt vector occurs and "wire OR" this with the K7 output of U4.

The generation of the vector select signal is shown in Fig. 3. The method used is the same as that illustrated on page 74 of the *User's Manual*. Whenever an interrupt vector is generated, AB15, AB14 and AB13 will go high and output 7 (pin 9) of U1 will go low; this will enable U3. Since AB12, AB11 and AB10 will also be high, output 7 (pin 9) of U3 will go low. This will force K7 on the KIM low and read the vector address from the KIM monitor program. This enables the programmer to handle the interrupts as he would in the basic unexpanded KIM.

The decoding for the 4K boards is different from the decoding shown in the KIM 65K expansion shown on page 74 of the *User's Manual*. Instead of generation of a select line for each 1K of memory, you need a select for every 4K. Since 4K of memory equals 1000 hex (AB12 high and all other address lines low), the four highest-order address lines are all that need to be decoded. The highest decoded address on basic KIM is 1FFF, which means we must start decoding at 2000 hex (AB13 high, all other address lines low).

In Fig. 3, U1 and U2 are used to generate the Board Select signals. AB15, AB14 and AB13 are used to select a line for each 8K of memory. Whenever the address is below 1FFF, the 0 output of U1 will be low and you will be in the basic KIM memory. When AB13 goes high (2000 hex), output 1 (pin 2) will go low. The KIM memory will be disabled and the B input (pin 14) of U2 will be high. AB12 will be low, making input A (pin 15) of U2 low. Output 2 (pin 3) of U1 will be high, making U2 input C (pin 13) low.

These input conditions on U2 will select output 2 (pin 3) of U2. Output 2 will remain enabled as long as the address is between 2000 hex and 2FFF. When 3000 hex is reached, AB12 will go high, changing the input A of U2 to a high, and output 3 of U2 will be enabled. This continues for other addresses with U1 selecting an 8K block and U2 dividing it into a low and high 4K block.

The decoder circuit in Fig. 2 will decode addresses 200 hex to 5FFF. By using outputs 3 and 4 of U1, The decoder will work

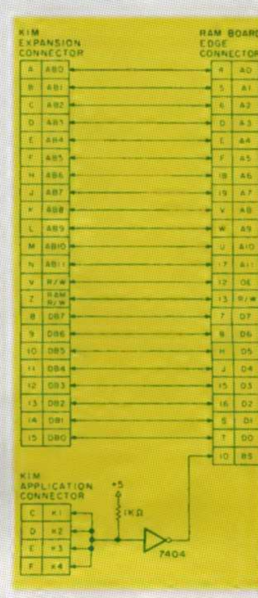


Fig. 2. 4K memory expansion.

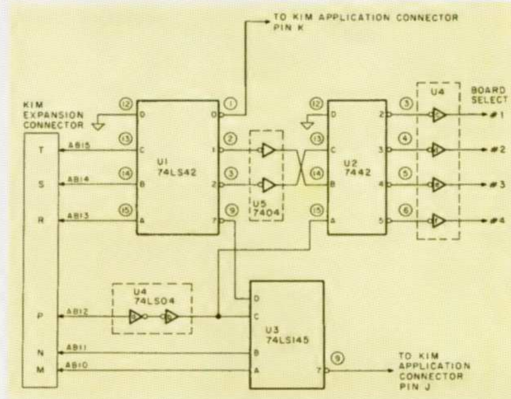


Fig. 3. 16K memory expansion.

from 6000 hex to 9FFF. Adding two more 7442 decoders to the U1 outputs allows expansion to 48K of RAM without any additional circuitry.

The outputs of U1 are active low and the inputs of U2 are active high, so the inverters of U5 are needed for the proper signal on the input to U2. The Board Selects for the memory cards are again active high, so the outputs of U2 must be inverted. U2 inverters A and B are used to reduce the loading on AB12.

Expansion Tips

I recommend three steps when you expand your KIM.

1. Use 74LS series TTL circuits because they are only 1/5 of a normal TTL load. If you choose not to do this then you must use buffers.

2. Use wire-wrap construction, as opposed to printed circuits. This will make construction much simpler and will make future changes and expansions easier.

3. Obtain a fairly heavy power supply. The KIM and four memory cards require about 3.1 Amps so a 5 Amp power supply is enough, but future expansion soon forces you to get another supply. A 10 Amp supply should allow expansion to a full 48K of RAM.

I constructed my expansion on a Vectorboard-punched terminal board. A 44-pin connector was mounted on one side of the card to mate with the KIM expansion connector. The other end was supported by 3/4 inch spacers. The motherboard for the memories was placed adjacent to the expansion board, which allowed the use of short wires for interconnections of about 7 inches.

After constructing the expansion, if nothing happens when you press KIM reset (RS), and the display remains blank, check pin 9 of U3. It should go low every time reset (RS) is pressed. If the board select is inoperative, the data byte will be the same as the high-order address byte.

The Atwood Enterprises memory card is an inexpensive and easy way to expand your KIM. The hardware needed to expand is minimal and there is no need to worry about S-100 bus compatibility. The board is available for $79.95 in kit form ($89.95 assembled and tested) from Kathryn Atwood Enterprises, PO Box 5203, Orange CA 92667.

Although not mentioned in my article, several other boards are available for use with the Atwood motherboard. These include an EPROM board, an I/O board and a KIM interface board that accomplishes the same expansion as the circuit I've described in this article (it sells for $24.95 kit and $34.95 assembled). ■