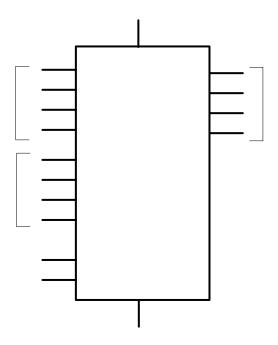# EXPERIMENT #9: MEMORY UNIT

## OBJECTIVES:

- Perform Read/Write operations with the RAM
- Simulate a ROM using a RAM
- Implement a combinational circuit using the ROM simulator

## Equipment and ICs:

- Mini-Lab ML-2001 lab station
- 1 - IC 7493 4-bit Ripple Counter
- 1 - IC 7489 16 x 4 RAM
- IC 7404 Hex Inverter gates

## Introduction:

A memory unit stores binary information in groups of bits called words. A word in memory is an entity of bits that move in and out of storage as a unit. The communication between a memory and its environment is achieved through data input and output lines, address selection lines, and control lines that specify the direction of transfer. A block diagram of IC 7489 16 x 4 RAM is shown below.

The 4 address inputs select one of 16 words in the memory. The least significant bit of the address is A0 and the most significant is A3. The chip select (CS) input must be equal to 0 to enable the memory. If CS is equal to 1, the memory is disabled and all four outputs are in a high impedance state. The write enable (WE) input determines the type of operation as indicated in the function table.

| | | |
|---|---|---|
| | | |

The write operation is performed when WE = 0. This is the transfer of the binary number from the data inputs into the selected word in memory. The read operation is performed when WE = 1. This transfers the complement value stored in the selected word into the output data lines. The memory has three-state outputs to facilitate memory expansion.

**ROM Simulator**
A ROM simulator is obtained from a RAM when operated in the read mode only. The pattern of 1's and 0's is first entered into the simulating RAM by placing the unit momentarily in the write mode. Simulation is achieved by placing the unit in the read mode and taking the address lines as inputs for the ROM. The ROM can then be used to implement any combinational circuit.

## Part 1: Testing the RAM

Store a few words into RAM and read them to verify the Write and Read operations.

### Pre-lab Work:

1. Read the **Introduction** section above.
2. Read Section 7-5 on ROM from the text book.

### Lab Work:

Connect IC 7489 for Read/Write operations on the proto-board following the directions given below.

1. Connect the address inputs to a binary counter using the IC 7493.
2. Connect the four data inputs to DIP switches and the data outputs to four 7404 inverters. (The data outputs are connected to inverters because the outputs produce the complement of the selected word in RAM).
3. Provide four indicator lamps for the address lines and four more for the outputs of the inverters.
4. Connect input CS to ground and WE to a DIP switch.
5. To write a word into the RAM, first set the address in the counter and the inputs in the four DIP switches connected to the four input data lines.
6. Flip the switch to the write position (0 value) and them return it to the read position (1 value). This will store the word (set by the four DIP switches) in the RAM (at the address set by the counter).
7. Store a few words into the memory and then read them to verify that the write and read operations are functioning properly.

**Important Notes**:
- Do not change the address of inputs when WE is in the write mode
- Always keep the WE input in the read mode, unless you want to write into memory.
- If you switch off the power after storing data into the RAM, then all data is erased.

**OBSERVATIONS**:

**Part 2: ROM Simulator**

Obtain a ROM simulator using the setup implemented in **Part 1** above.
Implement a combinational circuit using the ROM simulator that converts a 4-bit binary number to its equivalent Gray code as given in the table below.

| Decimal | Binary | Gray |
|---------|--------|------|
| 0 | 0000 | 0000 |
| 1 | 0001 | 0001 |
| 2 | 0010 | 0011 |
| 3 | 0011 | 0010 |
| 4 | 0100 | 0110 |
| 5 | 0101 | 0111 |
| 6 | 0110 | 0101 |
| 7 | 0111 | 0100 |
| 8 | 1000 | 1100 |
| 9 | 1001 | 1101 |
| 10 | 1010 | 1111 |
| 11 | 1011 | 1110 |
| 12 | 1100 | 1010 |
| 13 | 1101 | 1011 |
| 14 | 1110 | 1001 |
| 15 | 1111 | 1000 |

**Pre-lab Work:**

1. Read the **Introduction** section above.
2. Read Section 7-5 on ROM from the text book.

**Lab Work:**

1. Store the truth table of the code converter given above by setting the address inputs to the binary value and the data inputs to the corresponding Gray code. (Follow the same procedure as in **Part 1** above for writing data into the RAM).
2. After all 16 entries of the table are written in memory; connect the WE line to logic-1 permanently to set the ROM simulator.
3. Check the code converter by applying the inputs to the address lines and verifying the correct outputs in the data output lines.

**Important Notes**:
- Do not change the address of inputs when WE is in the write mode
- Always keep the WE input in the read mode, unless you want to write into memory.
- If you switch off the power after storing data into the RAM, then all data is erased.