

# CHAPTER

12

## Memory System

Up until this lab, you have been building the peripheral circuits which do things like power the circuit, perform the actions of the robot, or control timing. At last we will be installing the brain of the robot.



### Background

As you know by now, a memory chip holds a series of instructions for the robot to perform. Each instruction has a memory address assigned to it as it is programmed into the chip. An instruction is programmed into a certain location in memory by three steps: setting the binary address on the address input pins of the chip, setting the instructions on the four write data input pins, and making the read/write pin take a transition from low to high. The output lines of the chip provide instructions to the robot system when three things happen: the read/write pin is high, the output data pin is low, and the appropriate address is on the address lines. In addition, the memory has two chip select pins, which can deactivate all input/output operations. In order for the chip to work, the CS pin must be high, and the  $\overline{\text{CS}}$  pin must be low.

The address lines for the memory chip are controlled by another chip, the counter. The counter has 12 binary output pins, which means that it can count as high as  $2^{12}$  (4096). However, there are

only  $2^8$  (256) memory locations in the memory chip, so only the lowest 8 bits of the counter are used as address lines. The ninth bit jumps from 0 to 1 when 256 addresses have been provided to the memory chip, so a logic 1 on the 9th bit of the counter is used as a memory overflow detector. The 9th bit is connected to the  $\overline{CS}$  pin of the memory chip, so the memory chip is active until instruction 256 occurs. Also the 9th bit is connected to the LED, which will light up, telling the programmer that the chip is full of instructions. In addition, the counter is equipped with a reset pin. When a +5V signal is applied to the reset input, the output of the counter goes back to all zeros. This is used to set the instruction address back to zero when a reset instruction is encountered or when the user presses the reset button.



## Laboratory Exercises

You have already tested all of the surrounding circuitry, so all that needs to be done is to make sure both the counter and the memory chip operate correctly before plugging them into the PC board.

### Counter: Address Generation

The counter chip is numbered 4040, and is a 16 pin IC. The diagram is shown in Fig. 12.1. The counter has all output pins except for pins 8 and 16, which power the chip, and pins 10 and 11, which are the clock and reset inputs, respectively.

1. Attach a test LED and resistor as shown in Fig. 12.3, to the 4 LSBs (Least Significant Bits -- the smallest binary digits) of the counter (pins 9, 7, 6, and 5). Wire the reset input, pin 11, to ground initially.
2. Connect COMMON and +5V to your counter at pins 8 and 16 respectively.
3. Set your function generator for a 0V to 5V square wave at a frequency of 1.0Hz (1 pulse per second), and connect it to pin 10, the counter's clock input.
4. Connect the wire attached to the reset input to +5V and then reconnect it to ground. This should turn all of the

LEDs off.

5. Now, leaving reset pin connected to ground, you should see the LEDs counting up slowly in a binary manner. Does the output change on a low to high or high to low transition of the clock (you may either look at the clock with your scope or else attach another LED indicator to it)? Determine the order of the bits, from low to high as you watch the LEDs go on and off. You may wish to increase the function generator frequency to see the higher order bits count.

The memory chip is labeled 5101 and is a 22 pin chip. It is schematically shown in Fig. 12.2. Note that the chip gets powered through pins 22 and 8, not the corners - 22 and 11, as most digital ICs. The address lines are pins 1 through 7 and 21. For the chip to function pin 17 must be high, and pin 19 must be low. These are the chip select pins, CS and  $\overline{\text{CS}}$ , mentioned earlier. Chip select is normally used when many memory chips are wired in parallel. In this case, the robot disables chip select when the “teacher” has filled up the memory. This prevents the teacher from “wrapping around the address space” and starting to overwrite earlier instructions. Pin 18 is the output data enable pin. If it is low, then the data stored at the location determined by address lines will be placed on the output - pins 10,12,14, and 16. Pin 20 is the read/write select line. When this line is high the memory chip is reading the internal store and placing it onto the output lines. When this line is low, the control inputs - pins 9, 11, 13, and 15 - are stored in the currently addressed memory location. The rest of the pins are memory inputs and outputs as shown.

## Memory IC

1. Wire the data input lines, pins 9, 11, 13, and 15, to ground. Also wire pins 18, 19, and 20 to ground. Connect all 8 address lines to ground - we will characterize memory location 0 first.
2. Connect pin 17 to +5V.
3. Connect LEDs to the read out lines (pins 10,12,14,16) as shown in Fig. 12.3.
4. Power up the chip on pins 8 and 22. Be very careful to apply only 0V and +5V to this chip. You should measure the voltage with the DMM before connecting the power supply.

5. Leave pin 19 ( $\overline{CS}$ ) connected to ground, logic 0. Connect pin 20 ( $R/\overline{W}$ ) to +5V, logic 1 and pin 18 (Output data (OD)) to ground, logic 0. You might see some of the LEDs light up. This is because there is random information already stored in the chip.
6. Move the wire on OD, pin 18, to +5V, logic 1. Do the lights remain on?
7. Select a random combination of 1's and 0's for the input data lines, pins 9, 11, 13, and 15. With OD still off (connected to +5V), move the  $R/\overline{W}$  pin to ground (logic 0), and back to +5V, logic 1.
8. Now move the wire on OD, pin 18, back to ground (logic 0). Did the output change? Bring the  $R/\overline{W}$  pin down to ground and up to +5V again.
9. Select a new address by randomly connecting one of the address lines to +5V instead of 0V. Leave OD connected to ground, and write a different value into this memory location by setting the  $R/\overline{W}$  pin to 0. Set the  $R/\overline{W}$  pin back to 1 and verify that what you wrote remains on the output.
10. Now change the address back to your original one by reconnecting all of the address wires to 0V. Does the output still match the information you stored there?
11. Next, make pin 19 ( $\overline{CS}$ ) +5V, a logic 1. Try to write in instructions or read them out. You can't. A similar thing happens when pin 17 goes low.

**Robot  
Final  
Assembly**

Throughout the series of lab exercises we have attempted to instill in you a basic idea about how large systems are designed and debugged - by decomposition. This was the reason we had you test the operation of every subsystem as you completed it. The worst way to construct a large complex system is to build the whole thing, and then decide to start testing it. In Part 3 of this lab we start by again checking all of the subsystems of the robot.

1. Insert all of the ICs into the robot PC board except the memory chip. You should have installed all of the electrical components that came with your robot kit. There is one diode, D5, which has not been installed in a previous step. You should install it now. If there are any other components left, check over the schematic to see where they belong and install them.

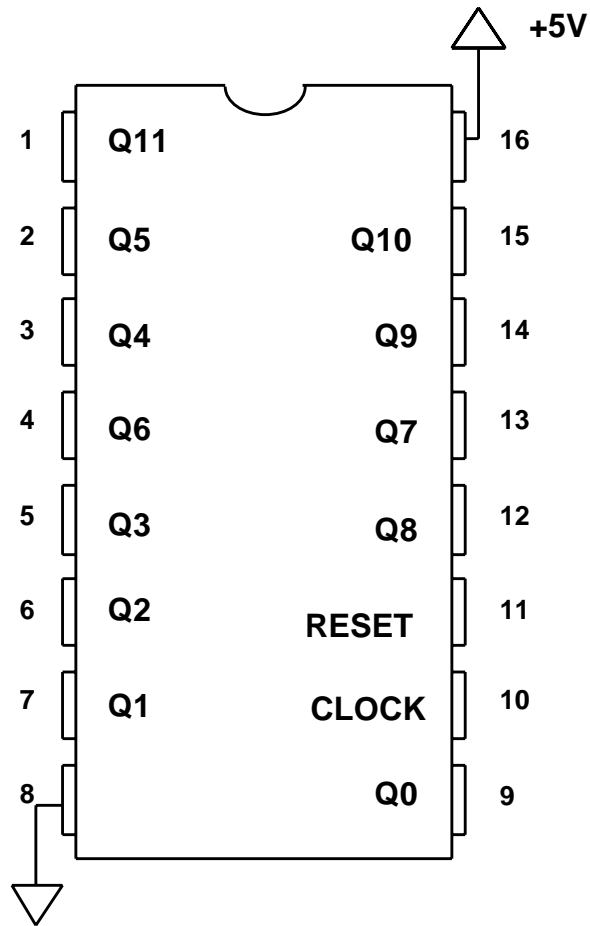
2. Set the +20V part of your power supply to +9V and attach it to the +9V pin of the robot PC board next to R9. Attach the power supply common to one of the GND pins of the robot PC board. Adjust the +6V part of your power supply to +3V and attach it to the +3V pin on the robot PC board. Attach both motors to the robot PC board. Check that the output of your voltage regulator is still +5V. Connect the teach pendant to the robot PC board.
3. We will now check out all of the signals connected to the memory chip. You can observe these signals by sticking a resistor lead into the appropriate pin of the memory chip 22 pin socket and grabbing that resistor lead with the scope probe.
4. The memory chip is labeled 5101 and is a 22 pin chip. It is schematically shown in Fig. 12.2. Check that the chip power is correct: +5V on pins 22 and 17, and 0V on pin 8.
5. Check the  $\overline{CS}$ , chip select, pin 19. It should be 0V, or if it is not, it should change to 0V when the RESET push-button switch is pressed (since this should reset the counter).
6. Verify that the robot's output circuits all work by applying a +5V signal at each of the output pins of the memory chip. This can be done by sticking a second resistor lead into pin 22 and using a clip lead to connect pin 22 to pin 10, 12, 14, or 16. Make sure that the resistors are not in series with this connection - hook the clip leads to the socket side of the resistors. You should observe the beeper beeping, the left motor turning, the right motor turning, and the light flashing.
7. Verify that the robot's input circuits all work by observing pins 9, 11, 13, and 15. They should all be low normally, but with the teach pendant plugged in they should go high when you press the Speaker, Left, Right, and Light buttons respectively.
8. With the teach pendant disconnected, you should observe that the address lines are counting upward. Note, because of the slow speed of the clock, you should look at the LSB of the address first, pin 21 on the memory chip. You may also wish to set the internal clock to its highest speed (about 4Hz). At that rate,  $\overline{CS}$ , pin 19, should be on for about 1 minute and off for about 1

minute.

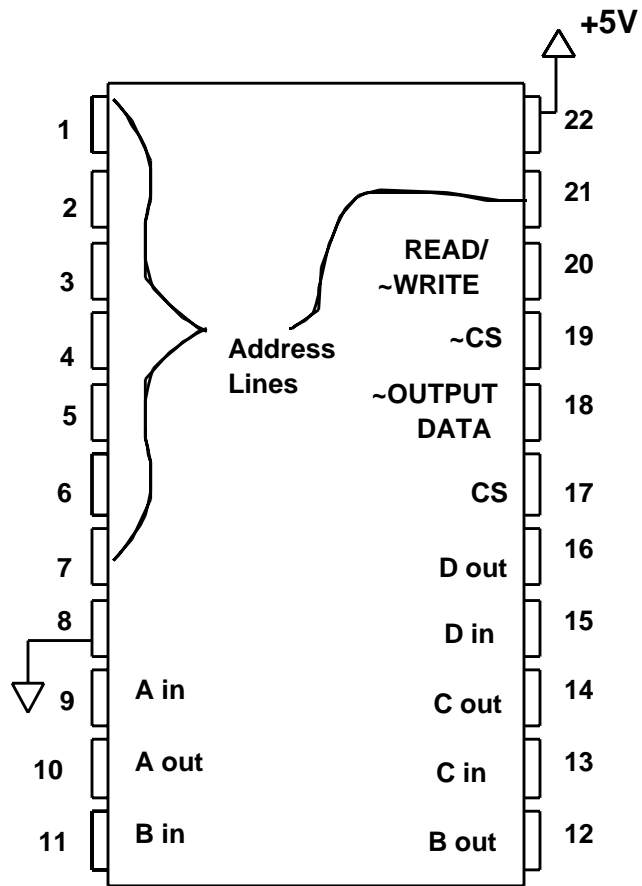
9. Congratulations, you may now plug the memory chip into the board and test the robot's complete operation. You should be able to store a program using the teach pendant and then run the program. Before coming to lab you should read over pages 34-35 of the Graymark robot instruction manual describing operation of the robot.
10. Demonstrate your working robot PC board to the Lab TA.

**Robot  
Mechanical  
Assembly**

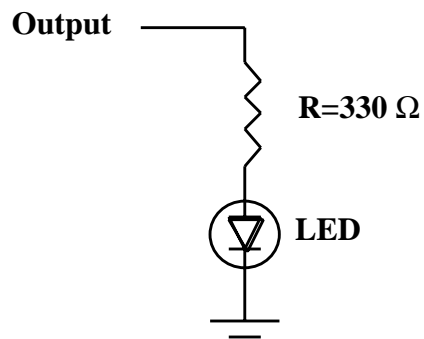
Once your robot is working electrically, then you may proceed to assemble the mechanics as described in the Graymark robot instruction manual. There are a few steps which require tools that may not be available to you (a small hammer and a very sharp Xacto Knife). These will be available in lab for your convenience.



**Figure 12.1** Pinout for the CMOS 4040 Counter.



**Figure 12.2** Pinout of the CMOS 5101 Static Random Access Memory.



**Figure 12.3** Using an LED to construct a digital signal indicator.