Chapter 7:
Monitoring and control systems

Learning objectives

By the end of this chapter you should be able to:

- show an understanding of monitoring and control systems
- show understanding of how bit manipulation can be used to monitor/control a device.

7.01 Monitoring systems

A monitoring system can be used to create a record of the condition of a system over a period of time. A monitoring system is used more often to detect when a particular physical property of a system goes outside a desired range; for example, if the CPU is too hot.

Discussion Point:

Set yourself a time limit of one minute. During this minute, by considering what measurement will be involved, ask yourself how many different types of monitoring system you can identify.

Let's consider temperature as an example. If this was being monitored under human control, the measurement could be made with a standard mercury thermometer. However, in this chapter we are interested in systems where a computer or microprocessor is being used. These systems require a measuring device that records a value which can be transmitted to the computer. Such a measuring device is a called a **sensor**. An example of a sensor for measuring temperature is a thermocouple, which outputs an electrical voltage that changes with temperature.

It is important to understand that in a monitoring system, a sensor does not have any built-in intelligence, so it cannot take any action if there is a problem. If the temperature measured becomes dangerously high it is the computer that sounds an alarm.

There are a wide variety of sensors available. For some the name indicates the property being measured such as pressure, humidity, carbon monoxide, pH or sound. For others such as an infrared sensor there are different methods of use. A passive infrared sensor just measures the level of infrared light received. In other cases, there is transmission of infrared light with the sensor possibly measuring the level of the light that is reflected back. Other sensors are given a generic name such as a motion sensor, for which different examples will be measuring different physical properties.

Question 7.01

How many different types of motion sensor are you aware of?

7.02 Control systems

A control system has the monitoring activity plus the capability to control a system. The control element of a monitoring and control system needs a device called an **actuator**. An actuator is an electric motor that is connected to a controlling device. It might be used for switching on or off or for adjusting a setting.

Discussion Point:

Refer back to the examples you identified as monitoring systems. How many were actually control systems? If they were monitoring systems could they be modified to become control systems?

Figure 7.01 shows a schematic diagram of a computer-controlled environment.

Note that Figure 7.01 includes an analogue-to-digital converter (ADC) and a digital-to-analogue converter (DAC) as separate components. In a real system they are likely to be integral to the sensor or actuator device.

For the system shown in Figure 7.01 there is a continuing process where the computer at regularly timed intervals signals the sensor to provide a measurement. If the measurement value received by the computer is not in the desired range the computer initiates a control action. The next timed measurement will happen after this control action has taken place. In effect this next measurement provides feedback to the computer on the effect of the control action. Feedback is essential in a control system.

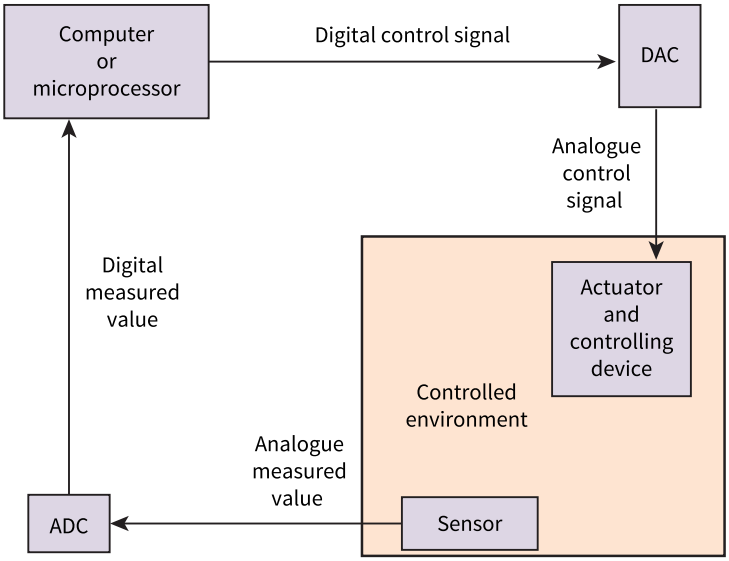

Figure 7.01 Computer-controlled environment

TIP

You need to remember that a sensor does not have any built-in intelligence so it cannot itself take any action if a problem occurs.

A closed-loop feedback control system is a special type of monitoring and control system where the feedback directly controls the operation. Figure 7.02 shows a schematic diagram of such a system. A microprocessor functions as the controller. This compares the value for the actual output, as read by the sensor, with the desired output. It then transmits a value to the actuator which depends on the difference calculated.

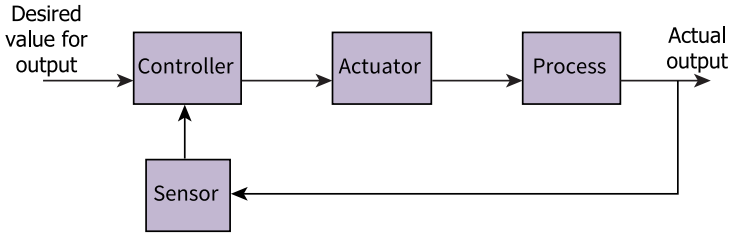

Figure 7.02 Closed-loop feedback control system

Question 7.02

Where would you be likely to find a closed-loop feedback control system?

7.03 Bit manipulation to control devices

The controlling computer or microprocessor has to have a real-time program running continuously. The program can set values for Boolean variables subject to what the sensors detect. For instance, if a controlled environment had two properties to be monitored and controlled, four Boolean variables could be used. Values could be set by assignment statements such as:

```
IF SensorDifference1 > 0 THEN Sensor1HighFlag ← TRUE
IF SensorDifference1 < 0 THEN Sensor1LowFlag ← TRUE
IF SensorDifference2 > 0 THEN Sensor2HighFlag ← TRUE
IF SensorDifference2 < 0 THEN Sensor2LowFlag ← TRUE
```

Another part of the monitoring and control program would then be checking whether any of the four flags were set. The machine code for running such a program could use individual bits to represent each flag. The way that flags could be set and read are illustrated by the following assembly language code fragments. In these code fragments the three least significant bits (positions 0, 1 and 2) of the byte are used as flags.

The following illustrates the setting of all bits to zero which might be used when the system is switched on.	
`LDD 0034`	Loads a byte into the accumulator from an address.
`AND #B00000000`	Uses a bitwise AND operation of the contents of the accumulator with the operand to convert each bit to 0.
`STO 0034`	Stores the altered byte in the original address.
The following illustrates the toggling of the value for one bit. This changes the value of the flag it represents. It might be needed because a problem has been encountered or alternatively because a problem has been solved.	
`LDD 0034`	Loads a byte into the accumulator from an address.
`XOR #B00000001`	Uses a bitwise XOR operation of the contents of the accumulator with the operand to toggle the value of the bit stored in position 0.
`STO 0034`	Stores the altered byte in the original address.
The following illustrates the setting of a bit to have value 1 irrespective of its existing value. This would be a simple way of just reporting a condition repetitively.	
`LDD 0034`	Loads a byte into the accumulator from an address.
`OR #B00000100`	Uses a bitwise OR operation of the contents of the accumulator with the operand to set the flag represented by the bit in position 2. All other bit positions remain unchanged.
`STO 0034`	Stores the altered byte in the original address.
The following illustrates setting all bits to zero except one bit which is of interest. Following this operation, a comparison can be made with a binary value to check if the bit is set. In this example the value would be compared to the binary equivalent of denary 2.	
`LDD 0034`	Loads a byte into the accumulator from an address.
`AND #B00000010`	Uses a bitwise AND operation of the contents of the accumulator with the operand to leave the value in position 1 unchanged but to convert every other bit to 0.
`STO 0034`	Stores the altered byte in the original address.

Reflection Point:

Are you clear that a bitwise logic operation acts on every bit individually; in effect all bits in the

accumulator are processed simultaneously?

Summary

- A monitoring system requires sensors.
- A sensor measures a physical quantity; there are many examples, such as temperature, humidity, pH, infrared, pressure, sound and carbon monoxide.
- A monitoring and control system requires sensors and actuators.
- A program used for a monitoring and control system has to operate in real time with an infinite loop that accepts input from the sensors at timed intervals.
- The program transmits signals to the actuators if the values received from the sensors indicate a need for control measures to be taken.
- Bit manipulation can be used within an assembly language program to monitor or control devices.

Exam-style Questions

1 A farmer has a large barn to house poultry for the purpose of collecting the eggs that are laid. The environment inside the barn affects the egg-laying performance of the poultry. Traditionally, the farmer had routinely entered the barn to check that all was well with the environment. If there was a concern, the barn had facilities for correcting the problem.

a More recently a computer-based system has been installed. This allows the farmer to observe data on a computer screen. If any of the data is of concern the system has been programmed to show a flashing red sign on the screen.

i Identify the type of system that the farmer has had installed. [1]

ii Identify the type of devices that have been installed inside the barn. [1]

iii Describe **two** examples of this type of device that could be used and explain what their purpose is with respect to the functioning of the computer-based system. [6]

b The farmer has been told that there is no need for someone to be watching a screen all of the time. A different type of computer-based system could be installed.

i Identify the type of this new computer-based system. [1]

ii Identify the new type of device that would need to be installed inside the barn. (There would be more than one needed). [1]

iii Describe how the new computer-based system would interact with these devices. [2]

2 An assembly language program has been written for a monitoring and control system. The program uses a byte stored in a register in which the bits can be individually set or cleared. An example is:

0	1	1	0	0	0	1	0

Bits 0–3 are set to 0 initially but if one of the two sensors in the system sends a measurement that indicates a problem (measurement is too high or too low) the appropriate bit is set to value 1. Bits 4–7 are also set to 0 initially but if an actuator has to be switched on or off the appropriate bit is set to 1.

a All of the bits in the register need to be set to 0. State which logical bitwise operation is required to be performed on the register content and give the operand that would be used for this. Complete your answer by filling in the boxes.

Logical bitwise operation is:

Performed with the operand:

[2]

b A sensor has recorded a value that is too high so bit 2 must be set to 1 but the other bits must remain unaltered. State which logical bitwise operation is required to be performed on the register content and give the operand that would be used for this. Complete your answer by filling in the boxes.

Logical bitwise operation is:

Performed with the operand:

[2]

c Bit 4 is set to 1 and bit 5 set to 0 but the sensor reading now indicates that there has been an over-reaction so the action of the actuator has to be reversed. This requires bits 4 and 5 to have their values toggled. State which logical bitwise operation is required to be performed on the register content and give the operand that would be used for this. Complete your answer by filling in the boxes:

Logical bitwise operation is:

Performed with the operand:

[3]

3 A gardener grows vegetables in a greenhouse. For the vegetables to grow well, the temperature needs to always be within a particular range.

The gardener is not sure about the actual temperatures in the greenhouse during the growing season. The gardener installs some equipment. This records the temperature every hour during the growing season.

a Name the type of system described. [1]

b Identify **three** items of hardware that would be needed to acquire and record the temperature data. Justify your choice for each. [6]

Item 1

Justification

Item 2

Justification

Item 3

Justification

c Part of the assembly code is:

	Op code	Operand
SENSORS:		B00001010
COUNT:		0
VALUE:		1
LOOP:	LDD	SENSORS
	AND	VALUE
	CMP	#0
	JPE	ZERO
	LDD	COUNT
	INC	ACC
	STO	COUNT
ZERO:	LDD	VALUE
	CMP	#8
	JPE	EXIT
	ADD	VALUE
	STO	VALUE
	JMP	LOOP
EXIT:	LDD	COUNT
TEST:	CMP	…
	JGT	ALARM

i Dry run the assembly language code. Start at `LOOP` and finish when `EXIT` is reached.

BITREG	COUNT	VALUE	ACC
B00001010	0	1	

[4]

ii The operand for the instruction labelled TEST is missing.

State the missing operand.

..... [1]

iii The intruder detection system is improved and now has eight sensors.

One instruction in the assembly language code will need to be amended.

Identify this instruction .....

Write the amended instruction ..... [2]

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