Time-Division Switching

EXERCISE OBJECTIVE

When you have completed this exercise, you will be familiar with time-multiplexed switching and time-division switching.

DISCUSSION

Introduction

To reduce the cost of the equipment required to transmit digitized voice signals and to simplify the interconnection of the line interfaces to the digital switching circuit of a central office, several digitized voice signals are transmitted through a single line. This is achieved by multiplexing in time the serial PCM codes produced by the CODEC of the line interfaces in a bank using a technique called time-division multiplexing (TDM).

The CODEC in each line interface produces 8-bit serial PCM codes at a rate of 8000 samples/s, that is, one code every 125 µs. In a central office using 24-channel TDM, 24 serial PCM codes must be transmitted during a 125-µs interval. To do so, this time interval is divided into 24 equal shorter time intervals, called time slots.

Each time slot is associated with a CODEC in one of the 24 line interfaces. Each CODEC is controlled so as to output one 8-bit serial PCM code on the TX line of the interface during the proper time slot. This results in a time-division multiplexed PCM signal (TDM-PCM signal) on the TX line that consists of a 192-bit string representing 24 digitized voice signals. Similarly, the CODEC in each line interface reads the bits during the proper time slot to demultiplex the 8-bit serial PCM codes received through the RX line.

Time-Multiplexed Switching

In a time-multiplexed switching circuit, a switching bus (consisting of a single transmit line) supports a large number of connections by interleaving signals from many sources which are physically separated from each other. The concept of time-multiplexed switching is shown in Figure 2-3. Each telephone set is connected to the switching bus via a gate, and the connection between two telephone sets is made via the switching bus.
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For example, telephone set 1 is connected to telephone set 2 by closing gates G1 and G2 during a certain time interval (time slot). By changing the connections for short periods of time in a cyclic manner, i.e., by continually changing the gates which are closed momentarily, the configuration of the switch is replicated once for each time slot. In brief, time-multiplexed switching essentially provides switching in space by sharing a single transmit line (switching bus) between many elements (telephones) connected to this line.

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Time-multiplexed switching allows switching of analog and digital signals in space. However, in today's central offices, switching in both the space and time domains is required to improve the capability, efficiency, and flexibility of the switching system. Switching in time is another dimension of switching and is referred to as time-division switching.

Time-division switching consists in moving data contained in each time slot of an incoming bit stream to a different time slot in an outgoing bit stream according to the destination of this data. This operation is also referred to a time slot interchange (TSI). To accomplish time-division multiplexing, data in the time slots of the incoming bit stream are stored in a memory following the order in which they occur, and then called out of memory in a different order, as shown in Figure 2-4.
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Figure 2-4. Time-division switching (time slot interchange) operation.

The major difference between time-division and time-multiplexed switching is that in a time-multiplexed switching system, data contained in each time slot of an incoming bit stream are not moved to a different time slot of the outgoing bit stream. Consequently, time-multiplexed switching does not require a memory to perform time slot interchange.

Figure 2-5 shows how two telephone sets can be interconnected using a time-division switch (time slot interchanger). In this system, the analog line interface (ALI) associated with each telephone set is assigned a unique time slot for both transmission and reception. For example, the ALI of telephone set 1 is assigned time slot 1, the ALI of telephone set 2 is assigned time slot 2, and so on. The ALI of telephone set 1 is connected to the ALI of telephone set 3 by transferring voice data in incoming time slot 1 to outgoing time slot 3. To have bidirectional communication, i.e. a path going from telephone set 3 to telephone set 1, voice data in incoming time slot 3 is transferred to outgoing time slot 1. By performing other time slot interchanges, other telephone sets (analog line interfaces) can be interconnected.

In the Telephony Training System, the ANALOG LINE INTERFACEs of telephone sets are interconnected using a form of switching in time where voice data never changes time slots. Each ALI is assigned one time slot for transmitting data and a second one for receiving data. The transmit (TX) time slot is fixed (it is equal to the TSAC address) while the receive (RX) time slot is variable according to the connection to be established. To connect the ALI of telephone set 1 (ALI 1) to the ALI of telephone set 3 (ALI 3) as in the previous example, ALI 1 is assigned time slot 1 for transmission and ALI 3 is assigned time slot 1 for reception. To have bidirectional communication, ALI 3 is assigned time slot 3 for transmission and ALI 1 is assigned time slot 3 for reception.
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![Diagram of a time-division switch](image)

Figure 2-5. Use of a time-division switch (time slot interchanger) to interconnect telephone sets.

The type of switching in time performed in the Telephony Training System is not real time-division switching because voice data never changes time slots. In fact, this is essentially like time-multiplexed switching described earlier in this discussion. The TXE and RXE signals related to an analog line interface play the role of the gates required to perform time-multiplexed switching. For the sake of simplicity, real time-division switching has not been retained in the Telephony Training System.

**Procedure summary**

In the first part of the exercise, you will set up a central office with the Telephony Training System (TTS).

In the second part of the exercise, you will configure the Control Register of the SPACE-DIVISION SWITCH in the SWITCHING CIRCUIT in order to simulate a hard-wired permanent connection between line TX0 of the ANALOG LINE INTERFACEs and line RX1 of the SERVICE CIRCUITs. You will then force the RX time slots of the SERVICE CIRCUITs at different values and observe that any of these circuits can be used to receive the DTMF dialing signal from any of the ANALOG LINE INTERFACEs. This will demonstrate that time-multiplexed switching allows several different connections to be made between the line interfaces and service circuits through a single physical line.
EQUIPMENT REQUIRED

Refer to Appendix A of this manual to obtain the list of equipment required to perform this exercise.

PROCEDURE

Setting Up the Central Office

1. Make sure that the Reconfigurable Training Module, Model 9431, is connected to the TTS Power Supply, Model 9408.
   Make sure that there is a network connection between the Reconfigurable Training Module and the host computer.
   Install the Dual Analog Line Interface, Model 9475, into one of the analog/digital (A/D) slots of the Reconfigurable Training Module.
   Connect two analog telephone sets to the Dual Analog Line Interface. Make sure that the tone dialing mode is selected on each analog telephone set.

   **CAUTION!**
   
   High voltages are present on the standard telephone connectors of the Dual Analog Line Interface. Do not connect or disconnect the analog telephone sets when the Reconfigurable Training Module is turned on.

   Connect the AC/DC power converter supplied with each analog telephone set to one of the AC power outlets on the TTS Power Supply. Connect the DC power output jack of each AC/DC power converter to the DC power input connector on either of the analog telephone sets.

   **Note:** The analog telephone set requires an auxiliary DC power source for the digital display to be operative.

2. Turn on the host computer.
   
   Turn on the TTS Power Supply, then the Reconfigurable Training Module.

3. On the host computer, start the Telephony Training System software, then download the CO program to the Reconfigurable Training Module. The CO program configures the Reconfigurable Training Module so that it operates as a central office.
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**Note:** If the host computer is unable to download the CO program to the Reconfigurable Training Module, it may not be using the proper IP address. Have your instructor check if the computer is using the proper IP address to communicate with the Reconfigurable Training Module.

4. On the host computer, make sure the address of the TSAC in ANALOG LINE INTERFACE A is set to 01. Set the address of the TSAC in ANALOG LINE INTERFACE B to 03.

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5. Zoom in on the SWITCHING CIRCUIT of the Central Office.
   
   Set the SPACE-DIVISION SWITCH control mode (SDS Control Mode) of the SWITCHING CIRCUIT to Manual. This will allow you to manually set (force) the connection(s) to be performed by the SPACE-DIVISION SWITCH for any given time slot.

6. Access the Control Register of the SPACE-DIVISION SWITCH (SDS Control Register) and fill in column TX0 Input Line with the number "01". This will simulate a hard-wired, permanent connection between input line TX0 and output line RX1 (this line is associated with the SERVICE CIRCUITs). Close the SDS Control Register window.

   Using the TIME SLOT SELECTOR in the SWITCHING CIRCUIT, successively select each time slot. While doing this, observe that the SPACE-DIVISION SWITCH effectively connects input line TX0 to output line RX1 during all time slots.

   **Note:** When 32-channel TDM is used, no connections are made during time slots 0 and 16. Consequently, the LVTTS software will not allow you to enter a value in the cells of rows Time Slot 0 and 16.

7. Connect Oscilloscope Probes 1 and 2 to TP4 (CODEC analog input) of ANALOG LINE INTERFACEs A and B, respectively.

   Connect Oscilloscope Probes 3 and 4 to TP7 (CODEC analog output of SERVICE CIRCUIT 1) and TP16 (CODEC analog output of SERVICE CIRCUIT 2) of the SIGNALING CIRCUIT, respectively.

8. Start the Oscilloscope.
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Make the following settings on the Oscilloscope:

Channel 1
- Mode: Normal
- Sensitivity: 0.5 V/div
- Input Coupling: DC

Channel 2
- Mode: Normal
- Sensitivity: 0.5 V/div
- Input Coupling: DC

Channel 3
- Mode: Normal
- Sensitivity: 0.5 V/div
- Input Coupling: DC

Channel 4
- Mode: Normal
- Sensitivity: 0.5 V/div
- Input Coupling: DC
- Time Base: 0.5 ms/div
- Trigger
  - Source: Ch 1
  - Level: 0.1 V
  - Slope: positive (+)
  - Display Refresh: Continuous

☐ 9. Set the Receive Time Slot Assignment Mode of the SIGNALING CIRCUIT to Manual. Then, force the receive (RX) time slot of SERVICE CIRCUIT 1 to 01, if not already set to this value.

☐ 10. Lift off the handset of telephone set A and depress different number keys on the keypad. (No dial tone is transmitted to telephone set A since switching is controlled manually).

Observe that the analog DTMF dialing signals at TP4 of ANALOG LINE INTERFACE A are recovered at TP7 of the SIGNALING CIRCUIT, but not at TP16 of the SIGNALING CIRCUIT, as if a physical connection was established between ANALOG LINE INTERFACE A and SERVICE CIRCUIT 1. Explain why.

Replace the handset of telephone set A on the cradle.
11. Force the RX time slot of SERVICE CIRCUIT 1 to 03, then lift off the handset of telephone set A and depress different number keys on the keypad.

You should observe that the analog DTMF dialing signals at TP4 of ANALOG LINE INTERFACE A are not recovered at TP7 of the SIGNALING CIRCUIT, as if the physical connection between ANALOG LINE INTERFACE A and SERVICE CIRCUIT 1 was not existing any longer. Explain why.

Replace the handset of telephone set A on the cradle.

12. Force the RX time slot of SERVICE CIRCUIT 2 to 01.

13. Lift off the handset of telephone set A and depress different number keys on the keypad.

Observe that the analog DTMF dialing signals at TP4 of ANALOG LINE INTERFACE A are recovered at TP16 of the SIGNALING CIRCUIT, but not at TP7 of the SIGNALING CIRCUIT, as if a physical connection was established between ANALOG LINE INTERFACE A and SERVICE CIRCUIT 2. Explain why.

Replace the handset of telephone set A on the cradle.

14. Lift off the handset of telephone set A, then lift off the handset of telephone set B. On the keypads of both telephone sets, simultaneously depress a different key.

While doing this, observe that the analog DTMF dialing signal from ANALOG LINE INTERFACE A is recovered by SERVICE CIRCUIT 2, while the analog DTMF dialing signal from ANALOG LINE INTERFACE B is recovered by SERVICE CIRCUIT 1.
Consequently, ANALOG LINE INTERFACEs A and B seem to be respectively connected to SERVICE CIRCUITs 2 and 1 through two distinct physical lines. Explain why.

Replace the handsets of telephone sets A and B on their cradles.

☐ 15. From the observations you have made up to this point, does time-multiplexed switching allow simultaneous connection of several devices through a single physical line, i.e., without the need for switching connections in space? Explain.

☐ 16. Calculate the maximum number of connections that the Central Office of the Telephony Training System is able to make between a bank of ANALOG LINE INTERFACEs and the SERVICE CIRCUITs when a single physical line exists between those devices.

☐ 17. On the host computer, close the Telephony Training System software.

Turn off the TTS Power Supply, as well as the host computer (if it is no longer required).

Disconnect the AC/DC power converters from the TTS Power Supply and the analog telephone sets.

Disconnect the analog telephone sets from the Dual Analog Line Interface.

Remove the Dual Analog Line Interface from the Reconfigurable Training Module.
CONCLUSION

In this exercise, you became familiar with time-multiplexed and time-division switching. You learned that both switching techniques provide connection of two physically separated circuits (line interfaces, service circuits, etc). You learned that time-multiplexed switching does not perform time slot interchange, that is, data remains in the same time slot as it is transferred from one circuit to another. On the other hand, you learned that time-division switching performs time slot interchange, that is, data changes time slot as it is transferred from one circuit to another.

You learned that the Telephony Training System performs time-multiplexed switching by dynamically assigning receive (RX) time slots to the line interfaces and service circuits. You saw that several different connections can be made between the ANALOG LINE INTERFACES and the SERVICE CIRCUITs through a single physical line. This occurs because time-multiplexed switching involves switching in the time domain, not switching between physical lines.

REVIEW QUESTIONS

1. How are circuits interconnected when time-multiplexed switching is used?

2. How are circuits interconnected when time-division switching is used?

3. What is the main difference between time-multiplexed switching and time-division switching?

4. Why is time-division switching used in modern digital central offices?
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5. In the Telephony Training System, how is data transferred from one ANALOG LINE INTERFACE to another using time-multiplexed switching?