Microprocessors in Signal Systems

Course 350

PARTICIPANT GUIDE

SIGNALS TRAINING CONSORTIUM

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Microprocessors in Signal Systems

Participant Guide

Signals Maintenance Training Consortium

COURSE 250

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Purpose of the Course

The purpose of the *Microprocessors in Signal Systems* course is to provide the participant with an introduction to microprocessors for signal maintainers. This introduction will include basic terminology; regulations and oversight specific to microprocessors; common components; common types of microprocessors; inspection, maintenance, and testing; and troubleshooting and repair.

Approach of the Book

This course begins with an outline, a statement of purpose and objectives, and a list of key terms. The *outline* will discuss the main topics to be addressed in the course. A list of *key terms* identifies important terminology that will be introduced in this course. *Learning objectives* define the basic skills, knowledge, and abilities course participants should be able to demonstrate to show that they have learned the material presented in the course. A list of *key terms* identifies important terminology that is introduced in this course. *Review exercises* conclude this course to assist the participants in reviewing key information.

Module 1

INTRODUCTION AND OVERVIEW TO MICROPROCESSORS IN SIGNAL SYSTEMS

Outline

Purpose and Objectives:

The purpose of this module is to provide the participant with an introduction to microprocessors. This introduction will include history of microprocessors, the main types of microprocessors in signal system, basic computer concepts and an introduction to Boolean logic.

Following the completion of this module, the participant should be able to complete the exercises with an accuracy of 70% or greater:

- Define microprocessor
- Describe the history of microprocessors
- Explain basic computer concepts
- Differentiate between relay logic and Boolean logic

Key Terms

- "And" Condition
- Application software
- Boolean logic
- Boolean Operators
- Buses
- Complimentary Metal-Oxide Semiconductor (CMOS) Battery
- Central Processing Unit (CPU)
- Computer case
- Computer network
- Computer software
- Computing system
- Control unit
- Chipset
- Desktop personal computer
- Device driver
- Dropline
- Downloading
- Dual Inline Memory Modules (DIMMs)
- Dynamic
- Dynamic Host Configuration Protocol (DHCP)
- Executive software
- Expansion cards
- Extender chassis
- Firewall
- Fixed media
- Hard disk drives
- Hardware upgrade
- Hosts
- Input devices
- Integrated Vital Processor Interlocking™ (iVPI)
- Internet Protocol (IP) address
- Lamp driver board
- Laptop personal computer
- Local IP address
- Main chassis
- Mainframe computer
- Malicious software
- MicroLok™
- MicroLok II™
- Motherboard
- Network nodes
- Network server
- Nodes
- "Not" Condition
- Operating system
- "Or" Condition
- Output devices
- peripherals
- Power supply unit (PSU)
- Programmable Logic Controllers (PLC)
- Public IP address
- Random Access Memory (RAM)
- Recycling
- Read Only Memory (ROM)
- Removable media
- Solid-state drives
- Stick circuit
- Storage devices
- Straight line
- System software
- Toxic materials
- Truth Tables
- Uploading
- Utilities
- Video card
- Vital Harmon Logic Controller™ (VHLC)
- Vital Logic Controller (VLC)
- Vital Microprocessor Interlocking System
- Vital Output Relay (VOR)
- Vital Processor Interlocking™ (VPI)

1-1 OVERVIEW

Rail systems are a multi-faceted with all components interrelated including interlockings, switches, fail safe mechanisms, track circuits, grade crossings and signals. In a microprocessor-based signal system, the microprocessor is the foundation of the system.

Figure 1 Microprocessor and Software Configuration as a Foundational Component of the Fail-Safe Design

For most of modern signal history and until more recent times, rail interlocking systems have depended on hard-wired network circuitry containing relays solid state technologies for logic signaling systems.

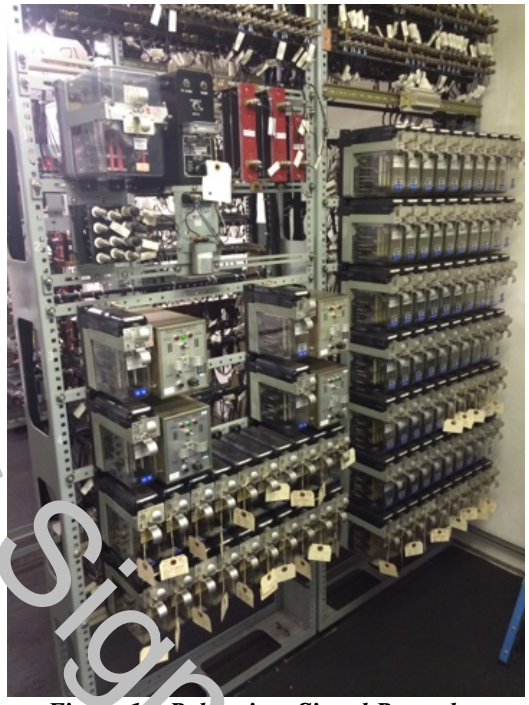

Figure 1.2 Relays in a Signal Bungalow

Since the late 1980s, these wired networks of relays and solid-state systems have been increasingly replaced by microprocessors containing software logic running on special-purpose control hardware. The fact that the logic is implemented by software rather than hard-wired circuitry greatly facilitates the ability to make modifications when needed by reprogramming rather than rewiring. In many implementations, this vital logic is stored as secure firmware or in **ROM** (Read Only Memory) that cannot be easily altered to both resist unsafe modification and meet regulatory safety testing requirements.

As part of the Vital Microprocessor Interlocking System (VMIS) systems, microprocessors are usually based on a Boolean and ladder logic format that digitally replicate standard relay circuitry logic. The VMIS and microprocessor have the additional design features to maintain fail-safe capability. This industry standard is developed through techniques that include viability of the software programs as well as sensing outputs and shutting down if the outputs are false and/or cannot be properly controlled.

In addition to no rewiring or adding relays to make logic changes, other advantages of microprocessors include having smaller bungalows and greatly reduced relay testing. There are still interface relays needed for a few functions, including OS track circuits, switch motor control and overload, switch locking, and the **Vital Output Relay (VOR)** which removes power sources to vital circuits in the event of a system fault in the **central processing unit (CPU)**, or the part of the microprocessor processing, computing and executing functions.

Figure 3 Vital Relay Output (VOR)

Figure 4 Vital Output Relay (VOR)

There are a number of manufacturers of VMIS equipment. For example, the Alstom microprocessor is the **Vital Processor Interlocking™ (VPI)**. The maintenance monitor, status and control panel and control monitor are shown in below. Alstom's latest design is the **Integrated Vital Processor System™ (IVPI)**.

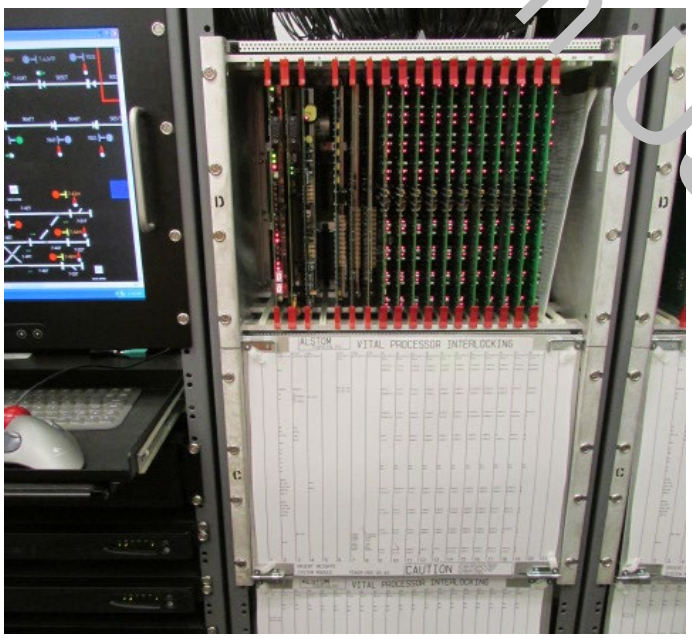

Figure 5 Internal View of a Vital Processor Interlocking (VPI™) System

The **MicroLok™** and **MicroLok II™** are the interlocking system from Union Switch and Signal ®, now Ansaldo STS). Notice the VOR, which MicroLok I™I terms as Vital Cut Off Relays (VCOR), at the top of the rack.

Figure 6 Microlok™ Interlocking System with VCORs

GE/Harmon (GETs) developed an interlocking system called a **Vital Logic Controller™ (VLC)** and later developed the **Vital Harmon Logic Controller™ (VHLC)** as an updated version of the VLC.

Figure 7 Vital Logic Controller VLC

Figure 8 VLC

1-2 COMPUTER BASICS

The microprocessor-based signal system is a computer-based signal system. Therefore, a signal maintainer responsible for maintaining and/or troubleshooting microprocessors and related systems should have a fundamental knowledge of computers, computer-based communication, and other related terms.

Computer Hardware and Software

Computers are made up of computer hardware and computer software. The combined hardware and software make up the **computing system**, and both are dependent on the other to function.

A **mainframe computer** is a much larger computer system that typically fills a room and may cost many hundreds or thousands of times as much as a personal computer. They are designed to perform large numbers of calculations for governments and large organizations. In transit organizations, the mainframe computer has historically housed in the central command center of the organization. Today most transit organizations utilize **network servers**.

Figure 9 Central Operations for SEPTA - courtesy of SEPTA

Figure 10 Part of SEPTA Mainframe Located in Central Operations - courtesy of SEPTA

Computer Hardware

The physical components of a computer are known as the **computer hardware**. Computer hardware includes a case, a monitor and keyboard, data storage, and a motherboard. Modern computers contain hardware such as a monitor, motherboard, a central processing unit (CPU), a random-access memory or RAM, two expansion card, a power supply, a hard disk drive, a keyboard and a mouse. Computers are often one of two type: a desktop personal computer or a laptop. A **desktop personal computer (PC)**, is usually larger, contains ta power-type case, and tends to not be mobile in nature. On the other hand, a **laptop personal computer** is more compact-style of computer that contains all hardware in one mobile unit. Laptops generally uses less power, contain reduced-size components and have lower performance. Laptops can be stationary but are also designed to be mobile, can be easily moved from one location to another, and can operate from an internal rechargeable battery.

Figure 11 Personal Desktop Computer

Figure 12 Personal Laptop Computer

The **computer case** encloses most of the components of the system. It provides mechanical support and protection for internal elements such as the motherboard, disk drives, and power supplies as well as controls the flow of cooling air over internal components. The case is also part of the system to control electromagnetic interference radiated by the computer and protects internal parts from electrostatic discharge. Large tower cases provide extra internal space for multiple disk drives or other peripherals and usually stand on the floor, while desktop cases provide less expansion room. Portable and laptop computers require cases that provide impact protection for the unit. A current development in laptop computers is a detachable keyboard, which allows the system to be configured as a touch-screen tablet.

A **power supply unit (PSU)** converts alternating current (AC) electric power to low-voltage DC power for the internal components of the computer. Laptops are capable of running from a built-in battery for a designed pre-determined amount of time.

The **motherboard** is the main component of a computer. It is a board with integrated circuitry that connects the other parts of the computer including the CPU, the RAM, the disk drives as well as any peripherals connected via the ports or expansion slots. Components directly attached to or to part of the motherboard include:

- Central Processing Unit (CPU)
- Chipset
- Random Access Memory (RAM)
- Read-only Memory (ROM)
- Busses
- Complimentary Metal-Oxide Semiconductor (CMOS) battery
- Video card

As part of the computer and as attached to the motherboard, the CPU performs most of the calculations which enable a computer to function. The motherboard is sometimes referred to as the brain of the computer. The **chipset** mediates communication between the CPU and the other components of the system, including main memory. **RAM**, or random access memory, stores the code and data that are being actively accessed by the CPU. For example, when a web browser is opened on the computer it takes up memory; this is stored in the RAM until the web browser is closed. RAM usually comes on **Dual Inline Memory Modules (DIMMs)** the sizes 2 gigabyte (GB), 4GB, and 8GB, but can be much larger. ROM stores Basic Input Output System (BIOS) which runs when the computer is powered on or otherwise begins execution, a process known as "booting up". Newer motherboards use Unified Extensible Firmware Interface (UEFI) instead of BIOS. **Busses** connecting the CPU to internal components as well as for graphics and sound expansion cards. The **CMOS battery** powers memory for the date and time in the BIOS chip, generally a watch battery. The **video card**, also known as the graphics card, processes computer graphics. Powerful graphics card are better suited for strenuous tasks such as complex video games.

Expansion cards in computers include a printed circuit board that can be inserted into an expansion slot of a computer motherboard or backplane to add functionality to a computer system via the expansion bus. Expansions cards can be used to obtain or expand on features not offered by the motherboard.

A **storage device** is any computing hardware and digital media that is used for storing, porting and extracting data files and objects. It can hold and store information both temporarily and permanently, and can be internal or external to a computer, server or any similar computing device. Data storage is a core function and fundamental component of computers.

Data is stored by a computer using a variety of media. **Fixed media** includes **hard disk drives** are found in virtually all older computers, due to their high capacity and low cost. **Solid-state drives** are faster and more power efficient often found in personal computers built in more recent times.

Removable media is used to transfer data between computers and include items such a USB flash drives and optical discs. Their usefulness depends on being readable by other systems; the majority of machines have an optical disk drive, and virtually all have at least one or more USB ports.

Peripherals include input and output devices are typically housed externally to the main computer chassis. The following are either standard or very common to many computer systems:

- **Input devices** - allow the user to enter information into the system or control its operation. Most personal computers contain some kind of mouse and keyboard combinations. Other input devices may also include webcams, microphones, joysticks, and image scanners.
- **Output devices** – displays information in a readable or usable form for human consumption. Output devices include printers, speakers, monitors, or Braille embossers.

Sometimes existing computers must be improved, meaning new hardware must be replaced or be added to the computer to improve performance, add capacity, or add features. This is known as a **hardware upgrade**.

Computer Software

Computer software is directed by the hardware to execute commands or instruction. Computer software can include system software, application software, and malicious software.

System software operates the computer hardware and provides the platform for application hardware to function. System software includes operating systems, device drivers and utilities.

- **Operating system** – the essential collection of software that includes boot loaders, shells, window systems and supervisory programs usually combined with some additional software including application software that will allow a user to use the computer.
- **Device driver** – the operation or control of a type of device attached to a computer. Computers typically need at least one input device and one output device at minimum, thus more than one device driver is needed.
- **Utilities** – computer programs to assist in the maintenance and care of a computer.

Application software allows the computer system to perform special functions beyond the basic computer operation and include examples such as database programs, word processors, Web browsers and spreadsheets. Application software is dependent on the type of computer hardware and system software included in the computer system.

Microprocessors use another type of software known as **executive software**. Executive software will be responsible for making some vital decisions within the microprocessor. The executive software also acts as the microprocessor's operating system. Executive software can be upgraded using development system tools when required.

Software that is developed for the intent of harming and disrupting computer systems is known as **malicious software**, or malware. Malware is usually associated with computer-related crimes.

Computer Communication

Computers process and store information and data. Additionally, computers may also share and communicate information and data with other computers and systems. The sharing of information and data between computers is known as a **computer network** or a data network. Computer networks provide a way for computers to exchange information between **nodes**, or data links. Wires, optic cables, or wireless media such as WiFi provide the means for establishing data links.

Network nodes are computer devices that allow the data to begin the transmission process, routing the data, and then finally ending the transmission process where the data route terminates. Nodes can include **hosts** such as computers, phones, servers and networking hardware. When two hosts can be connected for the purposes of exchanging information, or data, with each other they are considered networked.

Examples of applications and services supported by computer networks include the World Wide Web (www.); the use of email and instant messaging; shared use of application and storage servers, printers and fax machines; digital video; and digital audio. Computer networks vary in their transmission medium, or substance used for transmitting signals and data. Computers also vary in methods for organizing network data "traffic" that is being transmitted as well as the

"traffic control"; the network size; network topology, or the way in which the network is arranged; and general organization and goals.

A **router** is a networking device that forwards data between computer networks. Routers perform the traffic directing functions on the Internet. Routers typically allow all wired and wireless devices within range to use an available Internet connection. The router includes the **firewall** functionality. The firewall blocks potential malware or other security threats.

The main purpose of a **modem** is to produce a signal that is encoded and then decoded to reproduce original data which has been transmitted. Modems can be light-emitting diodes and radios, but most more commonly known them as associated with transmission of digital computer data modulated into an electric signals over a telephone line to then be demodulated to recover the transmitted data on the receiver end by a second modem. Modems are classified by the amount of data that can be transmitted typically expressed in bits or bytes per second.

Sometimes, modems and routers are combined into an integrated unit.

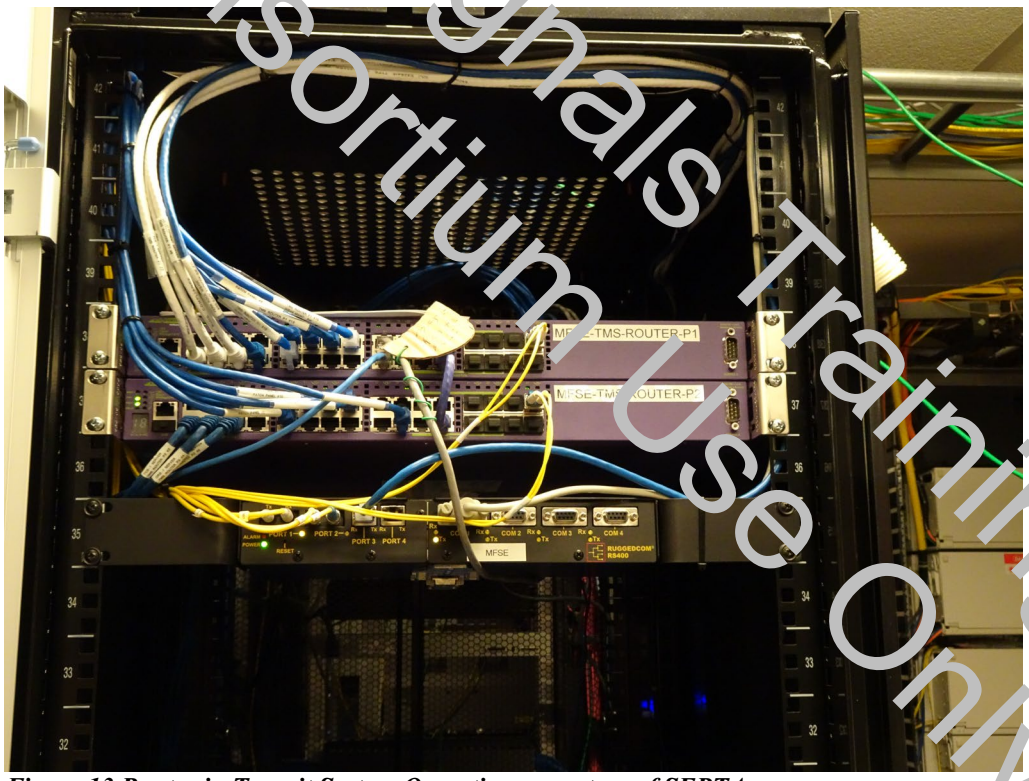

Figure 13 Router in Transit System Operation - courtesy of SEPTA

Figure 14 Modem in Transit System Operation - courtesy of SEPTA

The Internet and the IP Address

One of the best-known networks is the internet. Beginning in the 1960's and widely accessible to the public, the Internet is a global electronic communication network connecting computer networks and computers around the world including commercial, educational, government and other networks.

Like any home or business address providing a specific physical location with an identifiable address, devices on a network are differentiated from one another through IP addresses. Short for Internet Protocol, the **IP address** is the number identifying a piece of network hardware allowing devices to communicate with each other over IP-based networks. Like a combined house number, street, city, state and zip code that make a house address, the IP address is the address for the network hardware. Like mail is sent between addresses as it is sent from an originating destination to its final destination, IP addresses are used to transmit data with computers using DNS servers to look up hostnames to locate IP addresses.

Most IP addresses has a typical appearance. For example, an IP address will usually appear like the following:

- **IP address example 1** - 171.102.65.122

Or, sometimes, IP addresses may appear slightly different, such as the following:

- **IP address example 2** – 2002:4861:4861:9955

Like addresses can vary depending on location, so can IP addresses. IP addresses can be private, public, static and dynamic. An Internet Service Provider, or ISP, is a company that is paid a fee for internet access and service.

Sometimes referred to as a **local IP address**, private IP addresses are used for internal purposes that are not accessible by the public. Private IP addresses may represent a router that several pieces of network hardware or computers utilize. That router will contain a private IP address each device connected to the router will contain the same address with an additional number. For example, a router may have an address of 195.175.2.1 with the first device assigned the number 195.175.2.2 and the second device assigned 195.175.2.3 and so on.

Sometimes referred to as an Internet IP, a **public IP address** is used for any network hardware that is accessed via publicly and include IP addresses that are outside of any private network. Public IP addresses are assigned by an ISP.

Both private IP addresses and public IP addresses are either **dynamic**, meaning they change, or **static**, meaning they do not change.

An IP address that is assigned by a **Dynamic Host Configuration Protocol (DHCP)** server is a dynamic IP address. A DHCP provides quick automatic and central management for the distribution of IP addresses within a network. A device not using a DHCP enabled address or does not support it, and then the IP address must be assigned manually. A manually assigned IP in which case the IP address is called a static IP address.

Uploading and Downloading

Those using computers interacting with internet and systems may need to upload and / or download information. The term downloading refers to the receiving of data or a file from the network or system to a local computer. For example, if someone opens a file attached in an email, they have downloaded the file to their local computer. On the contrary, uploading refers to the process of sending data or a file from a local computer to somewhere on the internet. For instance, if someone attaches a file to an email and clicks "Send", the attachment has been uploaded to the internet and is being sent to a specified location as per the email address.

Computer Recycling

Recycling is a routine part of any organization, and this applies to computers as well. Creating computers requires materials and energy. Through recycling efforts, conservation can potentially be maximized, and pollution potentially reduced. Recycling also allows users to retain usable parts, such as hard drives, for further use in other computers. Some computers parts contain hazardous materials including lead, mercury, nickel, and cadmium. Laws governing the disposal of these parts must be followed.

Figure 15 Computer Recycling Considerations

Toxic Computer Components

The CPU contains many toxic materials including lead and chromium in the metal plates. Resistors, semi-conductors, infrared detectors, stabilizers, cables, and wires all contain cadmium. The circuit boards in a computer contain mercury and chromium. These materials and chemicals must be disposed of properly and according to agency policies and governing laws.

Classroom Activity 1.1

With guidance from your instructor, write down your agency's policy for recycling computers and computer parts.