Lesson 3.3 Synchronous Counters

**Preface**

As discussed in the previous lesson of this unit, the two categories of digital counters are asynchronous and synchronous. The analysis and design of synchronous counters is the topic of study of this lesson. The primary design characteristic of synchronous counters is that all of the flip-flops are all clocked simultaneously. This simultaneous clocking avoids the rippling effect that is present in asynchronous counters.

After completing a series of activities on the process for designing SSI and MSI synchronous counters, this lesson will conclude with a project that requires the students to design and simulate a circuit that counts the number of cars entering and leaving a parking garage.

**Concepts**

1.      Synchronous counters, also called parallel counters, are characterized by an external signal clocking all flip-flops simultaneously.

2.      Synchronous counters can be implemented using small scale integrated (SSI) and medium scale integrated (MSI) logic gates.

3.      Synchronous counters can be implemented with either D or J/K flip-flops.

4.      Up counters, down counters, and modulus counters all can be implemented using the synchronous counter method.

***Standards for Technological Literacy***

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| **Standard 1:  Students will develop an understanding of the characteristics and scope of technology.** | |
| **BM J:** | The nature and development of technological knowledge and processes are functions of the setting. |
| **BM K:** | The rate of technological development and diffusion is increasing rapidly. |
| **BM M:** | Most development of technologies these days is driven by the profit motive and the market. |
| **Standard 2:  Students will develop an understanding of the core concepts of technology.** | |
| **BM W:** | Systems’ thinking applies logic and creativity with appropriate compromises in complex real-life problems. |
| **BM X:** | Systems, which are the building blocks of technology, are embedded within larger technological, social, and environmental systems. |
| **BM Y:** | The stability of a technological system is influenced by all of the components in the system especially those in the feedback loop. |
| **BM Z:** | Selecting resources involves trade-offs between competing values, such as availability, cost, desirability, and waste. |
| **BM AA:** | Requirements involve the identification of the criteria and constraints of a product or system and the determination of how they affect the final design and development. |
| **BM FF:** | Complex systems have many layers of controls and feedback loops to provide information. |
| **Standard 3:  Students will develop an understanding of the relationships among technologies and the connections between technology and other fields of study.** | |
| **BM G:** | Technology transfer occurs when a new user applies an existing innovation developed for one purpose in a different function |
| **BM H:** | Technological innovation often results when ideas, knowledge, or skills are shared within a technology, among technologies, or across other fields. |
| **BM I:** | Technological ideas are sometimes protected through the process of patenting. The protection of a creative idea is central to the sharing of technological knowledge. |
| **BM J:** | Technological progress promotes the advancement of science and mathematics. Likewise, progress in science and mathematics leads to advances in technology. |
| **Standard 4:  Students will develop an understanding of the cultural, social, economic, and political effects of technology.** | |
| **BM H:** | Changes caused by the use of technology can range from gradual to rapid and from subtle to obvious. |
| **BM I:** | Making decisions about the use of technology involves weighing the trade-offs between the positive and negative effects. |
| **BM J:** | Ethical considerations are important in the development, selection, and use of technologies. |
| **BM K:** | The transfer of a technology from one society to another can cause cultural, social, economic, and political changes affecting both societies to varying degrees. |
| **Standard 6:  Students will develop an understanding of the role of society in the development and use of technology.** | |
| **BM H:** | Different cultures develop their own technologies to satisfy their individual and shared needs, wants, and values. |
| **BM I:** | The decision whether to develop a technology is influenced by societal opinions and demands, in addition to corporate cultures. |
| **BM J:** | A number of different factors, such as advertising, the strength of the economy, the goals of a company and the latest fads contribute to shaping the design of and demand for various technologies. |
| **Standard 9:  Students will develop an understanding of engineering design.** | |
| **BM I:** | Established design principles are used to evaluate existing designs, to collect data, and to guide the design process. |
| **BM J:** | Engineering design is influenced by personal characteristics, such as creativity, resourcefulness, and the ability to visualize and think abstractly. |
| **BM L:** | The process of engineering design takes into account a number of factors. |
| **Standard 10:  Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.** | |
| **BM J:** | Technological problems must be researched before they can be solved. |
| **BM L:** | Many technological problems require a multidisciplinary approach. |
| **Standard 11:  Students will develop abilities to apply the design process.** | |
| **BM N:** | Identify criteria and constraints and determine how these will affect the design process. |
| **BM P:** | Evaluate the design solution using conceptual, physical, and mathematical models at various intervals of the design process in order to check for proper design and to note areas where improvements are needed. |
| **BM Q:** | Develop and produce a product or system using a design process. |
| **BM R:** | Evaluate final solutions and communicate observation, processes, and results of the entire design process, using verbal, graphic, quantitative, virtual, and written means, in addition to three-dimensional models. |
| **Standard 12:  Students will develop the abilities to use and maintain technological products and systems.** | |
| **BM L:** | Document processes and procedures and communicate them to different audiences using appropriate oral and written techniques. |
| **BM M:** | Diagnose a system that is malfunctioning and use tools, materials, machines, and knowledge to repair it. |
| **BM N:** | Troubleshoot, analyze, and maintain systems to ensure safe and proper function and precision. |
| **BM O:** | Operate systems so that they function in the way they were designed. |
| **BM P:** | Use computers and calculators to access, retrieve, organize and process, maintain, interpret, and evaluate data and information in order to communicate. |
| **Standard 17:  Students will develop an understanding of and be able to select and use information and communication technologies.** | |
| **BM L:** | Information and communication technologies include the inputs, processes, and outputs associated with sending and receiving information. |
| **BM M:** | Information and communication systems allow information to be transferred from human to human, human to machine, machine to human, and machine to machine. |
| **BM N:** | Information and communication systems can be used to inform, persuade, entertain, control, manage, and educate. |
| **BM O:** | Communication systems are made up of source, encoder, transmitter, receiver, decoder, storage, retrieval, and destination. |
| **BM P:** | There are many ways to communicate information, such as graphic and electronic means. |
| **BM Q:** | Technological knowledge and processes are communicated using symbols, measurement, conventions, icons, graphic images, and languages that incorporate a variety of visual, auditory, and tactile stimuli. |

***National Science Education Standards***

**Standard K-12: Unifying Concepts and Processes:**  As a result of activities in grades K-12, all students should develop understanding and abilities aligned with the following concepts and processes;

         Systems, order, and organization

         Evidence, models, and explanation

         Change, constancy, and measurement

         Form and function

**Standard A: Science As Inquiry:** As a result of activities in grades 9-12, all students should develop;

         Abilities necessary to do scientific inquiry

         Understandings about scientific inquiry

**Standard E: Science and Technology:** As a result of activities in grades 9-12, all students should develop

         Abilities of technological design

         Understandings about science and technology

**Standard F: Science in Personal and Social Perspectives:** As a result of activities in grades 9-12, all students should develop understanding of;

         Science and technology in local, national, and global challenges

***Principles and Standards for School Mathematics***

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| **Number and Operations:** | Instructional programs from pre-kindergarten through grade 12 should enable all students to; understand numbers, ways of representing numbers, relationships among numbers, and number systems; understand meanings of operations and how they relate to one another; compute fluently and make reasonable estimates. |
| **Algebra:** | Instructional programs from pre-kindergarten through grade 12 should enable all students to; understand patterns, relations, and functions; represent and analyze mathematical situations and structures using algebraic symbols;  use mathematical models to represent and understand quantitative relationships; analyze change in various contexts. |
| **Problem Solving:** | Instructional programs from pre-kindergarten through grade 12 should enable all students to; build new mathematical knowledge through problem solving; solve problems that arise in mathematics and in other contexts; apply and adapt a variety of appropriate strategies to solve problems; monitor and reflect on the process of mathematical problem solving. |
| **Communication:** | Instructional programs from pre-kindergarten through grade 12 should enable all students to; organize and consolidate their mathematical thinking through communication; communicate their mathematical thinking coherently and clearly to peers, teachers, and others; analyze and evaluate the mathematical thinking and strategies of others; use the language of mathematics to express mathematical ideas precisely. |
| **Connections:** | Instructional programs from pre-kindergarten through grade 12 should enable all students to; recognize and use connections among mathematical ideas; understand how mathematical ideas interconnect and build on one another to produce a coherent whole; recognize and apply mathematics in contexts outside of mathematics. |
| **Representation:** | Instructional programs from pre-kindergarten through grade 12 should enable all students to; create and use representations to organize, record, and communicate mathematical ideas; select, apply, and translate among mathematical representations to solve problems; use representations to model and interpret physical, social, and mathematical phenomena. |

***Standards for English Language Arts***

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| **Standard 3:** | Students apply a wide range of strategies to comprehend, interpret, evaluate, and appreciate texts. They draw on their prior experience, their interactions with other readers and writers, their knowledge of word meaning and other texts, their word identification strategies, and their understanding of textual features (e.g. sound-letter correspondence, sentence structure, context, graphics). |
| **Standard 4:** | Students adjust their use of spoken, written, and visual language (e.g. conventions, style, vocabulary) to communicate effectively with a variety of audiences and for different purposes. |
| **Standard 12:** | Students use spoken, written and visual language to accomplish their own purposes (e.g. for learning, enjoyment, persuasion, and the exchange of information). |

**Performance Objectives**

*It is expected that students will:*

         Know the advantages and disadvantage of counters designed using the synchronous counter method.

         Be able to analyze and design up, down and modulus synchronous counters using discrete D and J/K flip-flops.

         Be able to analyze and design up, down and modulus synchronous counters using medium scale integrated (MSI) circuit counters.

         Use Circuit Design Software (CDS) and Digital Logic Board (DLB) to simulate and prototype SSI and MSI synchronous counters.

**Assessment**

*Explanation*

         Students will explain in their engineering notebook what the common threads are between asynchronous and synchronous counters.

*Interpretation*

         What common household problems use flip-flops in their circuitry?

**Essential Questions**

1.      What is another name for synchronous counters?

2.      How are the clock inputs of a synchronous counter’s flip-flops connected?

3.      What is the process for designing synchronous counters implemented using discrete D and J/K flip-flops and medium scale integrated (MSI) circuit counters?

4.      What are the differences between a synchronous counter and a synchronous modulus counter?

5.      What is the process for designing up, down, and modulus synchronous counters?

**Key Terms**

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| **Asynchronous Counter** | Type of counter in which each flip-flop output serves as the clock input signal for the next flip-flop in the chain. |
| **Binary Counter** | Group of flip-flops connected in a special arrangement in which the states of the flip-flops represent the binary number equivalent to the number of pulses that have occurred at the input of the counter. |
| **Decade Counter** | Any counter capable of going through 10 different logic states. |
| **Down Counter** | Counter that counts from a maximum count downward to 0. |
| **Modulus** | The number of states through which a counter sequences before repeating. |
| **Modulus N Counter**  **(mod-n counter)** | A counter with a modulus of N. |
| **Synchronous Counter** | Counter in which all of the flip-flops are clocked simultaneously. |
| **Up Counter** | Counter that counts upward from 0 to a maximum count. |
| **Up/Down Counter** | Counter that can count up or down depending on how its inputs are activated. |

**Day-by-Day Plans**

*Time: 7 days*

**Day 1 – 3: Lesson Overview and Introduction to Synchronous Counters**

         The teacher will present [**Concepts**](mk:@MSITStore:C:\Documents%20and%20Settings\DAVID_ROEMER\Desktop\DE\DE_2009.chm::/Unit_3/L3_3SynchronousCounters.htm#concepts), [**Essential Questions**](mk:@MSITStore:C:\Documents%20and%20Settings\DAVID_ROEMER\Desktop\DE\DE_2009.chm::/Unit_3/L3_3SynchronousCounters.htm#questions), and [**Key Terms**](mk:@MSITStore:C:\Documents%20and%20Settings\DAVID_ROEMER\Desktop\DE\DE_2009.chm::/Unit_3/L3_3SynchronousCounters.htm#Terms) in order to provide a lesson overview.

         The teacher will present [**Synchronous Counters w/SSI Logic.ppt.**](mk:@MSITStore:C:\Documents%20and%20Settings\DAVID_ROEMER\Desktop\DE\DE_2009.chm::/Powerpoints/SynchronousCountersSSI.ppt)

         Students will take notes in their engineering notebooks/portfolios.

         The teacher will distribute and introduce [**Activity 3.3.1 SSI Synchronous Counters.**](mk:@MSITStore:C:\Documents%20and%20Settings\DAVID_ROEMER\Desktop\DE\DE_2009.chm::/Unit_3/Activities/A3_3_1SSISynchronousCounters.htm)

         Students will take notes in their engineering notebooks/portfolios.

         Students will work on Activity 3.3.1 SSI Synchronous Counters.

**Day 4 – 8: MSI Synchronous Counters**

         The teacher will present [**Synchronous Counters w/MSI Logic.ppt.**](mk:@MSITStore:C:\Documents%20and%20Settings\DAVID_ROEMER\Desktop\DE\DE_2009.chm::/Powerpoints/SynchronousCountersMSI.ppt)

         Students will take notes in their engineering notebooks/portfolios.

         The teacher will distribute and introduce [**Activity 3.3.2 MSI ’163 Synchronous Counter.**](mk:@MSITStore:C:\Documents%20and%20Settings\DAVID_ROEMER\Desktop\DE\DE_2009.chm::/Unit_3/Activities/A3_3_2MSI163SynchronousCounter.htm)

         Students will take notes in their engineering notebooks/portfolios.

         Students will work on Activity 3.3.2 MSI 4-Bit Synchronous Counters.

         The teacher will assist the students as needed.

         The teacher will assess student work using [**Activity 3.3.2 MSI 4-Bit Binary Synchronous Counters Answer Key.**](mk:@MSITStore:C:\Documents%20and%20Settings\DAVID_ROEMER\Desktop\DE\DE_2009.chm::/Unit_3/Activities/A3_3_2MSI163SynchronousCounterAnsKey.htm)

         The teacher will distribute and introduce [**Activity 3.3.3 MSI ‘193 Synchronous Counter**](mk:@MSITStore:C:\Documents%20and%20Settings\DAVID_ROEMER\Desktop\DE\DE_2009.chm::/Unit_3/Activities/A3_3_3MSI193SynchronousCounter.htm).

         Students will take notes in their engineering notebooks/portfolios.

         Students will work on Activity 3.3.3 MSI 4-Bit Binary Synchronous Up/Down Counters.

**Day 9 – 13: Now Serving Display Design Project**

         The teacher will distribute and introduce [**Project 3.3.4 Now Serving Display Design Project.**](mk:@MSITStore:C:\Documents%20and%20Settings\DAVID_ROEMER\Desktop\DE\DE_2009.chm::/Unit_3/Activities/P3_3_4NowServingDisplay.htm)

         Students will work on Problem 3.3.4 Parking Garage Counter Design Project.

**Instructional Resources**

Presentations

[**Synchronous Counters w/SSI Logic**](mk:@MSITStore:C:\Documents%20and%20Settings\DAVID_ROEMER\Desktop\DE\DE_2009.chm::/Powerpoints/SynchronousCountersSSI.ppt)

[**Synchronous Counters w/MSI Logic**](mk:@MSITStore:C:\Documents%20and%20Settings\DAVID_ROEMER\Desktop\DE\DE_2009.chm::/Powerpoints/SynchronousCountersMSI.ppt)

Word Documents

[**Activity 3.3.1 SSI Synchronous Counters**](mk:@MSITStore:C:\Documents%20and%20Settings\DAVID_ROEMER\Desktop\DE\DE_2009.chm::/Unit_3/Activities/A3_3_1SSISynchronousCounters.doc)

[**Activity 3.3.2 MSI ’163 Synchronous Counter**](mk:@MSITStore:C:\Documents%20and%20Settings\DAVID_ROEMER\Desktop\DE\DE_2009.chm::/Unit_3/Activities/A3_3_2MSI163SynchronousCounter.doc)

[**Activity 3.3.3 MSI ‘193 Synchronous Counter**](mk:@MSITStore:C:\Documents%20and%20Settings\DAVID_ROEMER\Desktop\DE\DE_2009.chm::/Unit_3/Activities/A3_3_3MSI193SynchronousCounter.doc)

[**Problem 3.3.4 Now Serving Display Design Project**](mk:@MSITStore:C:\Documents%20and%20Settings\DAVID_ROEMER\Desktop\DE\DE_2009.chm::/Unit_3/Activities/P3_3_4NowServingDisplay.doc)