Lesson 3.1 Flip-Flops and Latches

**Preface**

Sequential logic, the topic of study for this unit, has two characteristic that distinguish it from combinational logic. First, sequential logic must have a signal that controls the sequencing of events. Second, sequential logic must have the ability to remember past events. A keypad on a garage door opener is a classic example of an everyday device that utilizes sequential logic. On the keypad, the sequencing signal controls when a key can be pressed. The need to enter the pass-code in a specific order necessitates memory of past events.

These characteristics are made possible by a simple device called a flip-flop. The flip-flop is a logic device that is capable of storing a logic level and allowing this stored value to change only at a specific time. For this reason the flip-flop is the fundamental building block for all sequential logic designs.

In this lesson we will begin the study of sequential logic by examining the basic operation of the two most common flip-flop types, the D and J/K flip-flops. As part of this analysis, we will review the design of four typical flip-flop applications: event detector, data synchronizer, frequency divider, and shift register. In later lessons, the application of flip-flops for asynchronous counters, synchronous counters, and state-machines will be studied.

**Concepts**

1.      The flip-flop and transparent latch are logic devices that have the capability to store data and can act as a memory device.

2.      Flip-flops and transparent latches have both synchronous and asynchronous inputs.

3.      Flip-flops can be used to design single event detection circuits, data synchronizers, shift registers, and frequency dividers.

**Standards and Benchmarks Addressed**

***Standards for Technological Literacy***

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| **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 FF:** | Complex systems have many layers of controls and feedback loops to provide information. |
| **Standard 9:  Students will develop an understanding of engineering design.** | |
| **BM K:** | A prototype is a working model used to test a design concept by making actual observations and necessary adjustments. |
| **Standard 10:  Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.** | |
| **BM I:** | Research and development is a specific problem-solving approach that is used intensively in business and industry to prepare devices and systems for the marketplace. |
| **BM J:** | Technological problems must be researched before they can be solved. |
| **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

         Form and function

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

         Understandings about science and technology

***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. |
| **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 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 schematic symbols and excitation tables for the D and J/K flip-flops.

         Describe the function of the D and J/K flip-flops.

         Describe the function of, and differences between, level sensitive and edge sensitive triggers.

         Describe the function of, and differences between, active high and active low signals.

         Describe the function of, and differences between, a flip-flop’s synchronous and asynchronous inputs.

         Draw detailed timing diagrams for the D or J/K flip-flop’s Q output in response to a variety of synchronous and asynchronous input conditions.

         Analyze and design introductory flip-flop applications such as event detection circuits, data synchronizers, shift registers, and frequency dividers.

         Use Circuit Design Software (CDS) and a Digital Logic Board (DLB) to simulate and prototype introductory flip-flop applications.

**Assessment**

*Interpretation*

         Students will make journal entries reflecting on their learning and experiences. Example of prompts for the general entries: Write about what you learned in class today. What is something you learned today that you did not understand or know before?

*Application*

         Students will demonstrate and explain to another student the difference between and active high and active low signals.

**Essential Questions**

1.      What is the basic function of a flip-flop and transparent latch?

2.      What functions do the synchronous and asynchronous inputs serve on flip-flops and transparent latches? Provide an example of each.

3.      What are some of the typical applications of flip-flops? Describe how each of these applications work.

**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. |
| **Asynchronous Inputs** | Flip-flop inputs that can affect the operation of the flip-flop independent of the synchronous and clock inputs. |
| **Clock** | Digital signal in the form of a rectangular pulse train or a square wave. |
| **Clocked D Flip-Flop** | Type of flip-flop in which the D (data) input is the synchronous input. |
| **Clocked J-K Flip-Flop** | Type of flip-flop in which inputs J and K are the synchronous inputs. |
| **D Latch** | Circuit that contains a NAND gate latch and two steering NAND gates. |
| **Duty Cycle (DC)** | Fraction of the total period that a digital waveform is in the HIGH state. DC = th/T (often expressed as a percentage: %DC = th/Tx100%). |
| **Edge-Sensitive** | Manner in which a flip-flop is activated by a signal transition. A flip-flop may be either a positive- or a negative-edge-triggered flip-flop. |
| **Falling Edge** | The part of a pulse where the logic level is in transition from a HIGH to a LOW. |
| **Flip-Flop** | A sequential circuit based on a latch whose output changes when its CLOCK input receives a pulse. |
| **Frequency** | The number of cycles per unit time of a periodic waveform. |
| **Level-Sensitive** | Enabled by a logic HIGH or LOW level. |
| **Period** | The amount of time required for one complete cycle of a periodic event or waveform. |
| **PRESET** | Asynchronous input used to set Q=1 immediately. |
| **Propagation Delays (tPLH/tPHL)** | Delay from the time a signal is applied to the time when the output makes its change. |
| **RESET / CLEAR** | Asynchronous input used to set Q=0 immediately. |
| **Rising Edge** | The part of a pulse where the logic level is in transition from a LOW to a HIGH. |
| **Sequential Logic** | Digital circuitry in which the output state of the circuit depends not only on the states of the inputs, but also on the sequence in which they reached their present states. |
| **Shift Register** | Digital circuit that accepts binary data from some input source and then shifts these data through a chain of flip-flops one bit at a time. |
| **State Machines** | A sequential circuit that advances through several defined states. |
| **Synchronous Counter** | Counter in which all of the flip-flops are clocked simultaneously. |
| **Trigger** | Input signal to a flip-flop or one-shot that causes the output to change states depending on the conditions of the control signals. |

**Day-by-Day Plans**

*Time: 3 days*

**Day 1: Lesson Overview and Introduction to Flip-Flops and Latches**

         Students will participate in a teacher-led discussion on sequential logic. The discussion will center on common everyday devices that are based on the design principal of sequential logic (the ability to hold or remember data). This will lead directly into the introduction of flip-flops and latches.

         The teacher will present [**Concepts**](mk:@MSITStore:C:\Documents%20and%20Settings\DAVID_ROEMER\Desktop\DE\DE_2009.chm::/Unit_3/L3_1FlipFlopLatches.htm#concepts), [**Essential Questions**](mk:@MSITStore:C:\Documents%20and%20Settings\DAVID_ROEMER\Desktop\DE\DE_2009.chm::/Unit_3/L3_1FlipFlopLatches.htm#EssentialQuestions), and [**Key Terms**](mk:@MSITStore:C:\Documents%20and%20Settings\DAVID_ROEMER\Desktop\DE\DE_2009.chm::/Unit_3/L3_1FlipFlopLatches.htm#terms) in order to provide a lesson overview.

         The teacher will present [**Introduction to Flip-Flops and Latches.ppt.**](mk:@MSITStore:C:\Documents%20and%20Settings\DAVID_ROEMER\Desktop\DE\DE_2009.chm::/Powerpoints/FlipFlopsLatches.ppt)

         Students will take notes in their engineering journals.

         The teacher will distribute and introduce [**Activity 3.1.1 Introduction to Flip-Flops.**](mk:@MSITStore:C:\Documents%20and%20Settings\DAVID_ROEMER\Desktop\DE\DE_2009.chm::/Unit_3/Activities/A3_1_1IntroductionFlipFlops.htm)

         Students will work on Activity 3.1.1 Introduction to Flip-Flops.

         The teacher will assist students as needed.

**Day 2 – 3: Flip-Flop Applications**

         The teacher will present [**Flip-Flop Applications.ppt.**](mk:@MSITStore:C:\Documents%20and%20Settings\DAVID_ROEMER\Desktop\DE\DE_2009.chm::/Powerpoints/FlipFlopApplications.ppt)

         Students will take notes in their engineering journals.

         The teacher will distribute and introduce [**Activity 3.1.2 Flip-Flop Application.**](mk:@MSITStore:C:\Documents%20and%20Settings\DAVID_ROEMER\Desktop\DE\DE_2009.chm::/Unit_3/Activities/A3_1_2FlipFlopApplications.htm)

         Students will work on Activity 3.1.2 Flip-Flop Application

         The teacher will assist students as needed.

**Instructional Resources**

Presentations

[**Introduction to Flip-Flops and Latches**](mk:@MSITStore:C:\Documents%20and%20Settings\DAVID_ROEMER\Desktop\DE\DE_2009.chm::/Powerpoints/FlipFlopsLatches.ppt)

[**Flip-Flop Applications**](mk:@MSITStore:C:\Documents%20and%20Settings\DAVID_ROEMER\Desktop\DE\DE_2009.chm::/Powerpoints/FlipFlopApplications.ppt)

Word Documents

[**Activity 3.1.1 Introduction to Flip-Flops**](mk:@MSITStore:C:\Documents%20and%20Settings\DAVID_ROEMER\Desktop\DE\DE_2009.chm::/Unit_3/Activities/A3_1_1IntroductionFlipFlops.doc)

[**Activity 3.1.2 Flip-Flop Application**](mk:@MSITStore:C:\Documents%20and%20Settings\DAVID_ROEMER\Desktop\DE\DE_2009.chm::/Unit_3/Activities/A3_1_2FlipFlopApplications.doc)