Digital Arithmetic

Originally, the basic arithmetic circuits were designed using discrete components, but this method has long been superseded by the introduction of MSI circuits. Multi-bit adders, arithmetic logic units and other circuits are now available as medium scale integrated circuits.

Digital Arithmetic Circuit

An arithmetic circuit is a set of gates with a separate set of inputs for each number that has to be processed.The gates are connected so as to carry out an arithmetic action and the outputs of the gate circuit are the digits of the result (addition, subtraction, multiplication, or division).

These circuits can be operated with binary values 0 and 1.

Examples of Arithmetic Circuits

Binary Adder

This a circuit, which performs the addition of two binary numbers.

Example

Half Adder

Half adder is a combinational circuit, which performs the addition of two binary numbers A and B are of single bit. It produces two outputs sum, S & carry, C.

The Truth table of Half adder is shown below.

(Table)

When we do the addition of two bits, the resultant sum can have the values ranging from 0 to 2 in decimal. We can represent the decimal digits 0 and 1 with single bit in binary. But, we can’t represent decimal digit 2 with single bit in binary. So, we require two bits for representing it in binary.

the Boolean functions for each output are.

(Boolean functions)

circuit diagram of Half adder

(Diagram)

Full Adder

Is a combinational circuit, which performs the addition of three bits A, B and Cin. Where, A & B are the two parallel significant bits and Cin is the carry bit, which is generated from previous stage. This Full adder also produces two outputs sum, S & carry, Cout, which are similar to Half adder.

Truth table of Full adder

(Truth table)

When we do the addition of three bits, the resultant sum can have the values ranging from 0 to 3 in decimal. We can represent the decimal digits 0 and 1 with single bit in binary. But, we can’t represent the decimal digits 2 and 3 with single bit in binary. So, we require two bits for representing those two decimal digits in binary.

Boolean functions for each output

circuit diagram of Full adder

(Diagram)

This adder is called as Full adder because for implementing one Full adder, we require two Half adders and one OR gate. If Cin is zero, then Full adder becomes Half adder.(verify with the truth table)

4-bit Binary Adder

The 4-bit binary adder performs the addition of two 4-bit numbers. Let the 4-bit binary numbers, A=A3A2A1A0 and B=B3B2B1B0. We can implement 4-bit binary adder in one of the two following ways.

Use one Half adder for doing the addition of two Least significant bits and three Full adders for doing the addition of three higher significant bits.

Use four Full adders for uniformity. Since, initial carry Cin is zero, the Full adder which is used for adding the least significant bits becomes Half adder.

The block diagram of 4-bit binary adder

(Diagram)

This binary adder is also called as ripple carry binary adder because the carry propagates ripples from one stage to the next stage.

Binary Subtractor

The morning subtraction of two binary numbers is known as Binary subtractor. We can implement Binary subtractor in following two methods.

Cascade Full subtractors

2’s complement method

(Math programs)

Intra System Communication Protocols

The Intra system protocol establishes communication between components within the circuit board. In embedded systems, intra system protocol increases the number of components connected to the controller.

Types of Intra System Communication Protocols

I2C Protocol

SPI Protocol

CAN Protocol

I2C Communication Protocols

Inter Integrated Circuit (I2C) is a serial communication protocol developed by Philips Semiconductors. The main purpose of this protocol is to provide easiness to connect peripheral chips with microcontroller. In embedded systems, all peripheral devices are connected as memory mapped devices to the microcontroller.

I2C necessitates two wires SDA (Serial Data Line) and SCL (Serial Clock Line) to carry information between devices. These two active wires are said to be bidirectional.

Advantages of I2C Communication Protocol

Provides good communication between onboard devices which are accessed infrequently

Addressing mechanism eases master slave communication

Cost and circuit complexity does not end up on number of devices

Disadvantages of I2C Communication Protocols

The biggest disadvantage of I2C Communication Protocols is its limited speed.

Serial Peripheral Interface (SPI) Communication Protocols

SPI (Serial Peripheral Interface) is one of the serial communication protocol developed by Motorola. It is a 4-wire protocol namely MOSI (Master Out Slave In), MISO (Master In Slave Out, SS (Slave Select), and SCLK (Serial Clock).

SPI is a full duplex communication protocol. SPI doesn’t limit data transfer to 8 bit words.

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Home Digital Technology Communication Protocols Communication Protocols in Embedded Systems – Types, Advantages & Disadvantages

Communication Protocols in Embedded Systems – Types, Advantages & Disadvantages

ByAbinayaa B-

Communication Protocols are a set of rules that allow two or more communication systems to communicate data via any physical medium. The rules, regulations, synchronization between communication systems, syntax to be followed and semantics are all defined by the term protocol. Protocols can be implemented by both hardware and software or combination of both. Analog and digital communication systems use various communication protocols widely. In addition, each protocol has its own application area.

Communication Protocols in Embedded Systems

Embedded System is an electronic system or device which employs both hardware and software. A processor or controller takes input from the physical world peripherals like sensors, actuators etc., processes the same through appropriate software and provides the desired output.

In this case, the components have to communicate with each other to provide the anticipated output. Each communicating entity should agree to some protocol to exchange information. Many different protocols are available for embedded systems and are deployed depending upon the application area.

Introduction to Communication Protocols

Fig. 1 – Introduction to Communication Protocols

In general, the communication protocols is associated with physical layer describing the signals incorporated, signal strength, hand shaking mechanism, bus arbitration, device addressing, wired or wireless, data lines etc.

The processes such as system configuration, selection of baud rate and transmitting & receiving data is associated with application layer.

Types of Communication Protocols in Embedded Systems

Communication protocols are broadly classified into two types:

Inter System Protocol

Intra System Protocol

Classification of Communication Protocols

Fig 2 – Classification of Communication Protocols

Inter System Communication Protocols

Inter system protocols establish communication between two communicating devices i.e. between PC and microprocessor kit, developmental boards, etc. In this case, the communication is achieved through inter bus system.

inter system

Fig. 3 – Inter System Communication Protocols

Types of Inter System Communication Protocols

Inter system protocol can be categorized into:

USB Communication protocols

UART Communication protocols

USART Communication protocols

USB Communication Protocols

Universal Serial Bus (USB) is a two-wired serial communication protocol. It allows 127 devices to be connected at any given time. USB supports plug & play functionality.

USB protocol sends and receives the data serially between host and external peripheral devices through data signal lines D+ and D-. Apart from two data lines, USB has VCC and Ground signals to power up the device. The USB pin out is shown in Figure 4 below.

USB Pinout

Fig. 4 – USB Pin Out

Data is transmitted in the form of packets where two devices communicate each other. Data packets compose of 8 bits (byte) with LSB (Least Significant Bit) transmitted first.

USB associates NRZI (Non Return to Zero Invert) encoding scheme to transmit data with sync field to synchronize the host system and receiver clock signals.

In USB, data is transferred in three different speeds such as:

usb speeds

Fig. 5 – USB speeds

Advantages of USB Communication Protocol

The advantages of USB Communication Protocol are as follows:

Fast and simple.

It is of low cost.

Plug and Play hardware.

Disadvantages of USB Communication Protocol

The disadvantages of USB Communication Protocol are as follows:

Needs powerful master device.

Specific drivers are required.

UART Communication Protocols

Universal Asynchronous Receiver/Transmitter (UART) is not a communication protocol but just a physical piece of hardware which converts parallel data into serial data. Its main purpose is to transmit and receive data serially.

UART is also two-wired i.e., the serial data is handled by Tx (Transmitter) and Rx (Receiver) pins.

UART transmits data asynchronously, which induces that no clock signal is associated in transmitting and receiving data. Instead of clock signal, UART embed start and stop bits with actual data bits, which defines the start and end of data packet.

When receiver end detects the start bit, it starts to read the data bits at specific baud rate meaning both transmitting and receiving peripherals should work under same baud rate. UART works under half duplex communication mode meaning it either transmits or receives at a time.

UART Frame

Fig. 6 – UART Frame

Example: Emails, SMS

USART Communication Protocol

Universal Synchronous Asynchronous Receiver/Transmitter (USART) is identical to that of UART with only added functionality synchronous. That is, the transmitter will generate a clock signal which will be recovered at the receiver end from the data stream transmitted without knowing baud rate ahead.

UART works under full duplex communication mode meaning it can transmit and receive data at same time.

USART encompass the abilities of UART, which enables application of both depending on the applications area.

USART Frame

Fig. 7 – USART Frame

Example: Telecommunications

Advantages of UART/ USART Communication Protocol

The advantages of UART/ USART Communication Protocol are as follows:

Clock signal is not required

Cost effective

Uses parity bit for error detection

Requires only 2 wires for data communication

Disadvantages of UART/ USART Communication Protocol

The disadvantages of UART/ USART Communication Protocol are as follows:

Doesn’t support multiple master slave functionality

Baud rate of communicating UART should be within 10 percent of each other

Intra System Communication Protocols

The Intra system protocol establishes communication between components within the circuit board. In embedded systems, intra system protocol increases the number of components connected to the controller.

Increase in components lead to circuit complexity and increase in power consumption. Intra system protocol promises secure access of data from the peripherals.

Types of Intra System Communication Protocols

Intra system protocol can be categorized into:

I2C Protocol

SPI Protocol

CAN Protocol

I2C Communication Protocols

Inter Integrated Circuit (I2C) is a serial communication protocol developed by Philips Semiconductors. The main purpose of this protocol is to provide easiness to connect peripheral chips with microcontroller. In embedded systems, all peripheral devices are connected as memory mapped devices to the microcontroller.

I2C necessitates two wires SDA (Serial Data Line) and SCL (Serial Clock Line) to carry information between devices. These two active wires are said to be bidirectional.

I2C protocol is a master to slave communication protocol. Each slave is been provided with unique address. In order to establish communication, master device initially sends the target slave address along with R/W (Read/Write) flag. The corresponding slave device will move into active mode leaving other devices in off state.

Once the slave device is ready, communication starts between master and slave devices. One bit acknowledgment is replied by the receiver if transmitter transmits 1 byte (8 bits) of data. A stop condition is issued at the end of communication between devices.

Advantages of I2C Communication Protocols

The advantages of I2C Communication Protocols are as follows:

Provides good communication between onboard devices which are accessed infrequently

Addressing mechanism eases master slave communication

Cost and circuit complexity does not end up on number of devices

Disadvantages of I2C Communication Protocols

The biggest disadvantage of I2C Communication Protocols is its limited speed.

Serial Peripheral Interface (SPI) Communication Protocols

SPI (Serial Peripheral Interface) is one of the serial communication protocol developed by Motorola. It is a 4-wire protocol namely MOSI (Master Out Slave In), MISO (Master In Slave Out, SS (Slave Select), and SCLK (Serial Clock).

As I2C protocol, SPI is also a master to slave communication protocol. In SPI, the master device first configures the clock at a particular frequency. Furthermore the SS line is used to select the appropriate slave by pulling the SS line low where it is normally held high.

The communication is established between the selected slave and the master device as soon as appropriate slave device is selected.

SPI is a full duplex communication protocol. SPI doesn’t limit data transfer to 8 bit words.

Advantages of SPI Communication Protocols

Faster than asynchronous serial communication protocol.

Support multiple slaves connectivity.

Universally accepted protocol and low cost.

Disadvantages of SPI Communication Protocol

Requires more wires than other communication protocols.

Master device should control all slave communications (slave-slave communication is impossible).

Numerous slave devices leads to circuit complexity.

Advantages of CAN Communication Protocols

Low cost and reliable

Shows robust performance

Secured and fast protocol

Disadvantages of CAN Communication Protocol

Automotive oriented

Bit complex protocol

cache memory is a supplementary memory system that temporarily stores frequently used instructions and data for quicker processing by the central processing unit (CPU) of a computer

Cache holds a copy of only the most frequently used information or program codes stored in the main memory.

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