# Serial Communication Design In Embedded System

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# Contents




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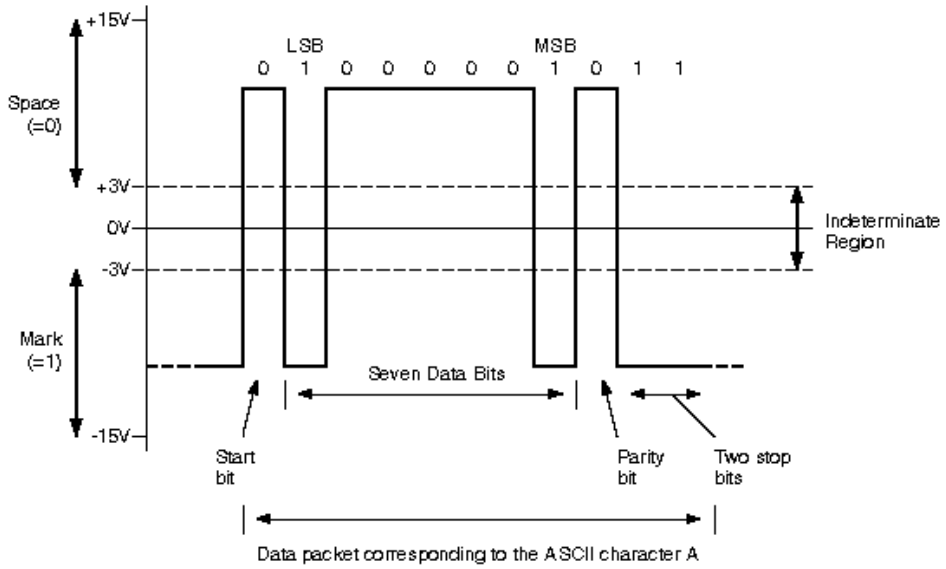
Serial communication is a significant design in Embedded System Design. This manuscript is going to analyze *RS-232*、*RS-422*、*RS485*、*$I^2C$*、*SPI*、*Microwire and 1-Wire*. These analyzes of Serial Communication design may help engineers acquire Serial Communication's features. Engineers will also be able to have more efficient information to approach their own designs.

Embedded System Design (ESD) has been apply to monitor, memory and to all sorts of communication technology. And yet, there are other factors that engineers need to consider. The below will shows 7 types of Serial Communication Design.

## The Advantages of Serial Design

**Serial** Interface Design often applied in the transmission of PC, because PC is based on a powerful Serial interface bus and there are few exceptions. Compare to the Embedded System of Universal Computer Interface, Serial Interface is more efficient than Expansion Bus, i.e. ISA or PCI.




**Serial** Interface only needs one I/O to communicate. However, Parallel Interface takes eight or even more. For example, Analog / digital converter and digital / analog converters, LCD and temperature sensors all supported to Serial Interface.

**Serial** Bus also applies to Internal processor communication (ex. Internet). Serial Bus connects low cost processors to complete a mission that usually rely on one big expansive processor. Moreover Serial Communication doesn't need to share memory or flags, which avoided many possible problems.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**However**, Parallel Interface/ Bus is still the best option in terms of Read bus, address bus and data bus, and other micro-program control. In address bus and data bus, Memory Mapping has become a special technology because it can access chip device in parallel. But 8-bit microcontroller (not to mention the 8-pin) doesn't have External address, therefore it doesn't usually apply Memory Mapping.

## Terminology

*Before we introducing each Interface, definitions are given*:

1. Asynchronous data bus doesn't require a clock signal, but synchronous bus is required
2. In Full-duplex mode, data can input and out put simultaneously, but in Half-duplex mode, you can only process the data respectively, not simultaneously
3. Subordination-Bus means one master device connects with many minor subs. They are usually synchronous, in two-way data transmission, the clock signal send out by master device.
4. Multi-master bus which means it has more than one master device. This bus must have an arbitration program, so that when the more than one master attempts to control the bus at the same time, this program will help to avoid conflicts.
5. Point to Point or (peer) Interface means two devices has a corresponding relationship; but no subordinate relationship. Point to Point Interface is non-synchronous.
6. When an interface with multiple receivers and a transmitter, we call it the "multipoint" (multi-drop) Interface.
7. When a bus has more than two Point to Point transceivers we call it the "multi-point" (multi-point). Unlike multi-drop, that it can be connected in the same set of two-way communication.

## RS-232 Interface

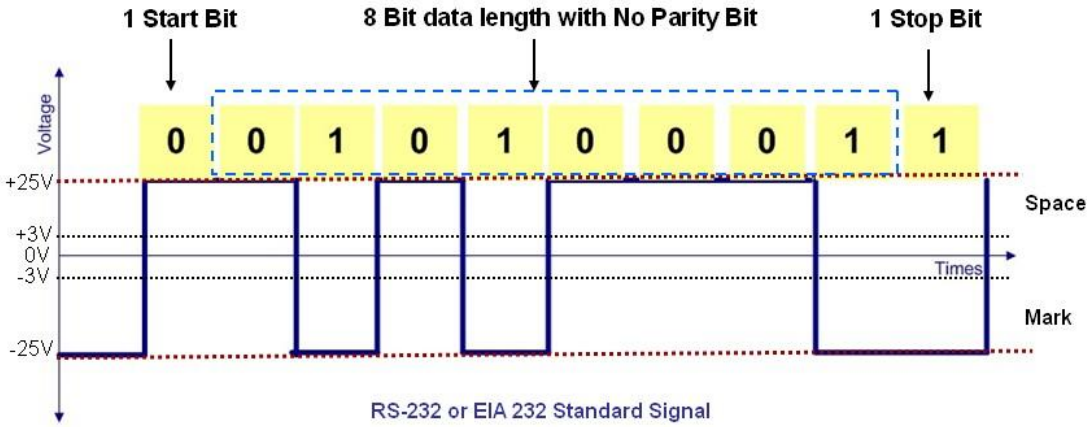
**Almost** all computers use TIA/EIA-232-F (RS-232) interface. RS-232 is almost a standard interface. It regulates the electrical characteristics, the physical and mechanical properties, such as the connecting of hardware, the output pin and signal. RS-232 is a Point to Point Interface. It's suitable for medium-length communication and its speeds can reach 20Kbps. Moreover, the regulation manual doesn't mention specifically that whenever in a shorter distance with a proper connection to the ground, the velocity can reach over 115.2Kbps. Usually RS-232 transmission distance is 30 feet, but when it transmit with low capacitance cable its distance can up to 200 feet.

**RS-232** is an non-balanced bus. It means the full-duplex communication is transmitting between two pairs of receiver / transmitter (data terminal equipment also called DTE and data circuit-terminating equipment DCE). Each end of the transmission signals are connected to the other end of receiving signals, thus, both ends of the pins are different.

**Each** transmitter sends out data by changing the voltage of the line. According to the binary system any voltage that is above 3V indicates with “0,”while the voltage is lower than-3V indicates with '1'. The voltage between these two values is undefined. RS-232 can be converter into IC, such as 1488, 1489 or MAX232, to process logic level (0V and 5V) and the voltage conversions.

**RS-232** communications usually includes start bit, data bits, parity bit (if any) and stop bit (sometimes multi-). The typical format of communication with PC is “the eight data bits,” no parity bit, one stop bit. In addition, seven data bits, a parity bit and a stop bit in this model is also very common. Usually, the start bit is 0 and the stop bit is 1, shown in Figure1.

**In** a formal specification, there is no description about the RS-232 communication protocols that including the usage of the start bit and the stop bits.




**Many** embedded systems process its interface by RS-232 and PC or PC peripherals (such as a modem). While other systems monitor bus traffic with a less expensive protocol analyzer or a PC with two serial ports together with RS-232.

**Almost** all of the microcontroller vendors have hard wares that support RS-232. It usually called Universal Asynchronous Receiver Transmitter (UART). UART is usually driven by interruptions. Its speed is up to 115.2Kbps. In addition, its software costs less. But the structures of UART are various.

## RS-422 and RS-485 interface

**TIA/EIA-422-B** ( RS-422) and TIA/EIA-485-A ( RS-485) is a balanced, twisted-pair interface. Its speed is up to 10Mbps, the transmission distance is up to 4,000 feet. RS-422 and RS-485 are differential bus, transmission of data with ± 1.5V to ± 6V signal. Compare to RS-232othernon-balanced single-ended bus, differential balanced bus has better noise immunity.

**RS-422** is a multipoint interface processing one-way communication on a pair of twisted-pair. Its capacity of receivers is 10 unit loads (UL). If the receiving device needed to communicate with the transmitter, you must connect each receiver and transmitter with a separate proprietary bus ( this circuit bus can function full-duplex communication). Because of this, RS-422 is seldom used for more than two nodes.

**RS-485** interface performs two-way communication between a number of transceivers by a twisted pair. Specification shows that the bus may include 32 equivalent transceivers unit load (UL). Some manufacturers produce branching (fractional) UL transceivers, which increase the number of connectable components to more than 100. The start bits, data bits and stop bits of RS-422 and RS-485 are basically the same with RS-232. In fact, many existing converters can perform data conversion between RS-232 and RS-485. But remember, RS-232 is a full-duplex interface, and RS-485.is half-duplex.

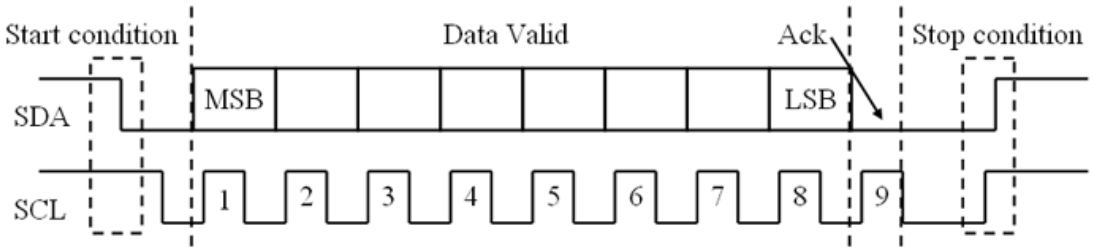
**Most** microcontroller manufacturers provide embedded UART, and claim to have a special RS-485 performance.

## $I^2C$ Bus interface

**Internal** $I^2C$ bus ($I^2C$) is a special interface developed by Philips Semiconductors. It is a half-duplex synchronous multi-master bus. It only needs two signal wire: serial data line (SDA) and serial clock line (SCL). In a connected interface, these signal line's voltage step-up by pulled through its resistors, and also control by the open-drain driver.

**$I^2C$** adopt addressable communications protocol, its master device communicate with a 7-bit or 10-bit address. Each element has an address the address is distributed to Component manufacturers by Philips Semiconductor manufacturers. There are also several special addresses, including "Total Call" (it can find any address with the bus), and "high-speed start address."

**While** communicating with the sub-device, all communication with the sub-clock signal (including to and back) is generated from the device. In the beginning, the master device will produce a start signal, an 8-bit data word, an acknowledge bit, and then a stop signal or repeating start signal. Except for the start signal and stop signal, each data bit are sent in when SCL is low. When SCL is high, SDA changes from high into low, which generates a start signal to start the data transmission. When SCL is high, SDA changes from low into high, sending out an end signals to end the data transmission (see Figure 2). Information receiving equipment generates the response bit by lowering SDA, and then the master device will release the line so that it can be remained high level of charge. If the response bit is high, the master device will consider that the data has not yet received from the final communication, and take appropriate action, if possible, the data will be retransmitted.

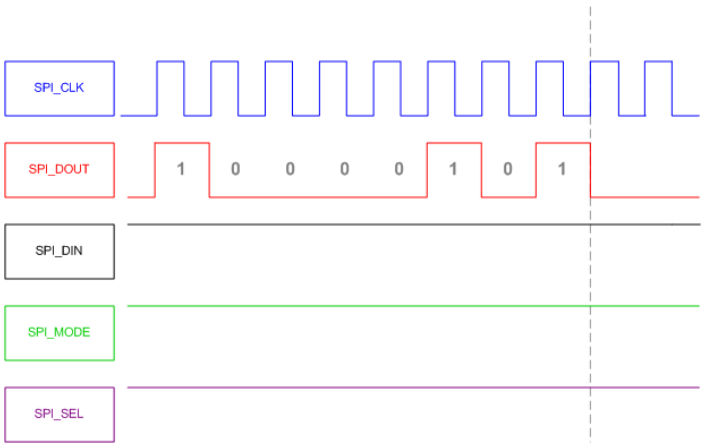



**I²C** has a very interesting feature called clock stretching. It happens when the devices can not handled data bits and required more time. In this case, the level of SCL line would fall. Because the signal shows '"connected", so when the master device will releases the SCL line to stretched the clock. The master device will notice that the line is still in a low level. At this point, the master device will wait until the processed data bits show up and release the line. Once the device released the line, SCL lines will restore to a high level and indicate the master device can send the next data bit.

**I²C** has tree rates: slow(less than 100Kbps), fast (400Kbps) and high-speed (3.4Mbps), each of which can be backward compatible. If you need to send the signal outside the circuit board, you may want to check the proposal composed by Philips standard connection method.

**Despite** rumors that someone had successfully used the I²C bus at a distant communication that over 50 feet, but its communicative distance is usually limited to the by its own circuit board. I²C communication distance is usually limited by bit rate of the bus and its traffic of the bus. Therefore, in terms of off-board communications, I²C often practices within 10 feet, it is considered to be a medium speed rate.

## SPI Bus interface




**Serial** peripheral interface (SPI) is a synchronous serial bus that developed by Motorola. It often applies to Motorola's microcontrollers.

**SPI** bus is composed by four signals, namely the Master Out Slave In (MOSI),Master In Slave Out (MISO), serial clock (SCK) and active low slave select (/ SS). SPI is a multi-master / slave communication protocol. The one-way communication between master and the selected devices are the MISO and MOSI. Its speed can reach more than 1Mbps and it's a full-duplex mode. SCK master device will generate a pulse and the data will be synchronized in both master and slave devices. There are four different clock types to define SIP protocol, depending on what the SCK polarity and phase may be. It must ensure these signals between the master and slave devices compatible with each other.

**Besides** the1Mbps rate of, SIP has another advantage: only when one slave device is activated, / the level of SS line will be low, / at this time SS signal can be generated without any master device. However, this performance depends on the choice of SCK phase.

**A** disadvantage of SPI is that each slave device requires an individual / SS line. If you have an external I/O pins or extra space for the external circuit board which makes multiplexer IC's installment possible. But for a multiple slave SPI interface, a small and a low pin microcontroller isn't a most desirable resolution.

## Microwire Bus interface

**Microwire** is a three-wire synchronous interface developed by the U.S. National Semiconductor. It's applied to National Semiconductor's COP8 processors.

**Similar** with SPI, Microwire is a master-slave bus, including the serial host device data (SO), the serial data that received by master device (SI) and clock signal (SK).

**These** are corresponding to SPI-MOSI, MISO and SCK. There is also a selected chip signal, its function is similar with SPI / SS. Microwire is a full-duplex bus, the speed can reach or exceed 625Kbps (determined by its capacitance).

**For** different needs, Microwire components follow different protocols. Different from 8-byte SPI, the length of data is variable in Microwire. It also provides a "continuous" mode which sort of like an idea like "bit per flow."

**Microwire** required many Chip Select lines due to its numerous sub-devices. Therefore, Microwire device can operate under SPI bus, although only under the condition of single-unit. Although the distance of SPI and Microwire communication can reach about 10 feet whenever with a low rate and capacity was configured properly, but they are still limited in within a board communications and the distance is farer than six inches.

## 1-Wire Bus interface

**The** Dallas Semiconductor's 1-Wire is an asynchronous master / slave bus. It is not used for more than one master device agreement. Similar to $I^2C$, 1-Wire adopts half-duplex communication while using single open-drain connection topology on two-way data transmission.1-Wireu is comparatively slower. Its maximum transmission rate can only up to 16Kbps. However, if the step-up of resistor configuration was properly settled, the transmission distance is able to reach 1,000 feet.

## Byte code monitoring

**If** the hardware does not support any bus from above, you can consider adopt the general I/O pins. The software that controls the Serial communication is usually called “byte code monitoring (bit banging).” Because the software functions as a monitoring role in the “serial port”

**Byte** code software requires the software is able to identify the correct sequences of each byte code, as it must monitor every bit code’s output as it changes (even in full-duplex interface, it has to receive data and monitor the situation.) Yet, there is a delightful ease for engineers that many monitoring program byte code can be found from the Internet data base. It can be used for all sorts of the serial bus, and almost all of the micro-controller structures. In fact, some of the micro-controller manufacturers have already published their own sources.

## Conclusion

**We** often have to face the tremendous and various standards of serial communication bus.

**When** choosing a serial bus, we should not only consider the current needs for the product, but also take into account whether the product can be used for the entire lifecycle. Hoping these information will help engineers select the most appropriate resolution for their current design of embedded serial interface.

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