A beginner-friendly introduction to the I2C protocol with diagrams

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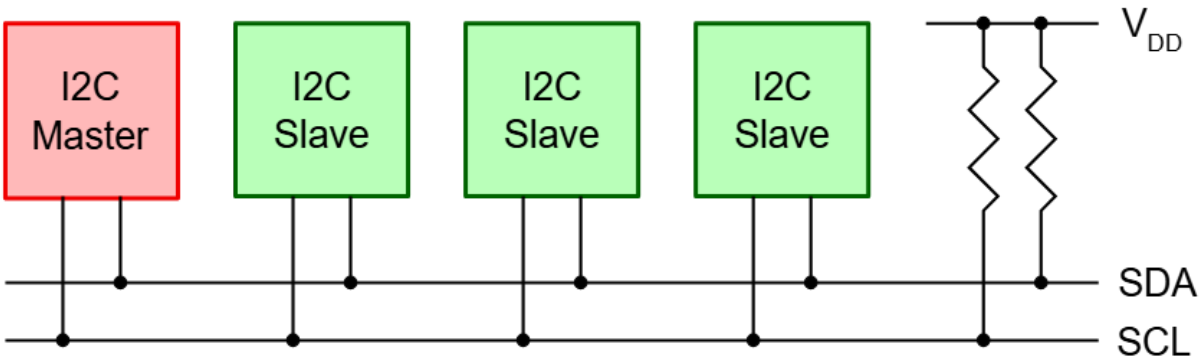
About I2C

I2C stands for inter-integrated circuit was developed in 1982 by Philips is one of the common serial protocols.As the name applies it is used primarily for short distance data communication.I2C is a synchronous master-slave type protocol where both master and slaves can send and receive data.It operates by directionally and half duplex mode and can run at different clock speeds.Only two wires Serial Data Line (SDA) and Serial Clock Line (SCL) are used in I2C for data communication.

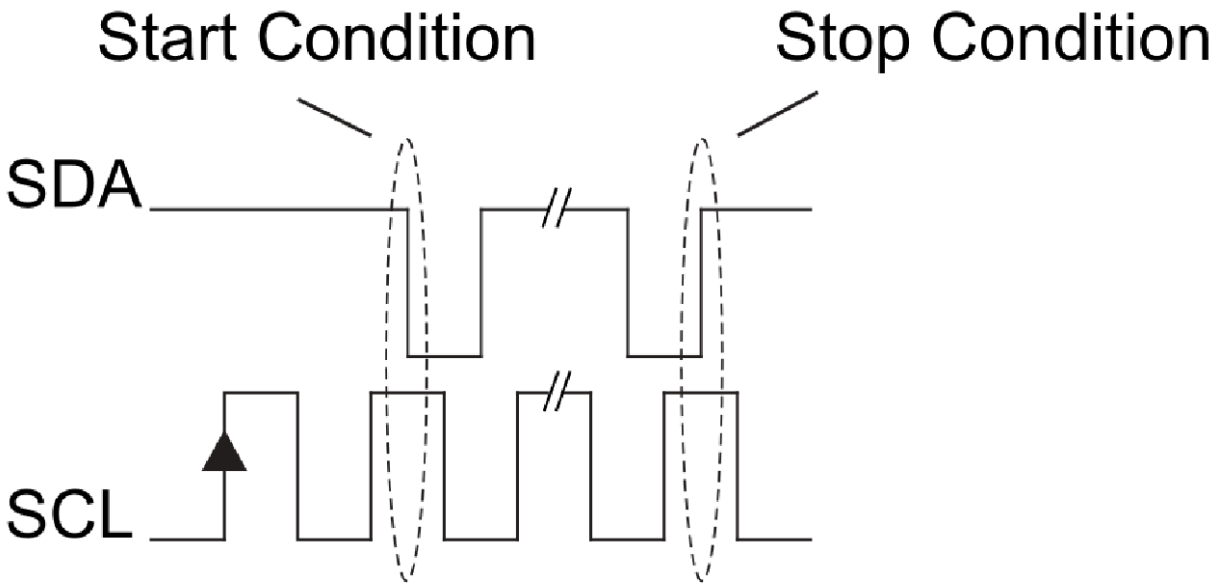
I2c Topology



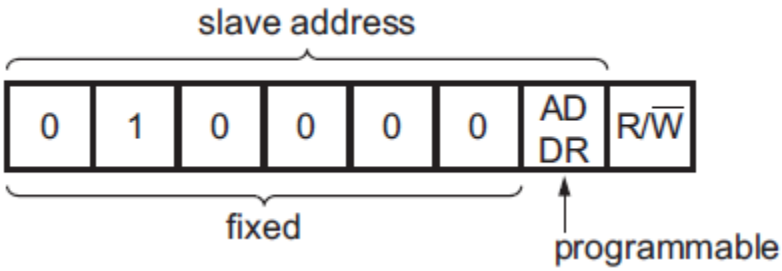
A master is connected to one or more slave nodes via two shared lines, SDA (Serial Data Line) and SCL (Serial Clock Line). These two lines are connected to a voltage source by a single pull-up resistor. Devices can be added to or removed from the bus at any location at any time.

Data Transmission Methods of I2C

1. **Start condition:**In the idle state of an I2C both SDA and SCL are high.Start condition occurs when a node first pulls SDA low and then pulls SCL low.Pulling these lines down in this order is used to claim the bus.Now the node that claims the bus is the master.The master device then starts the communication.



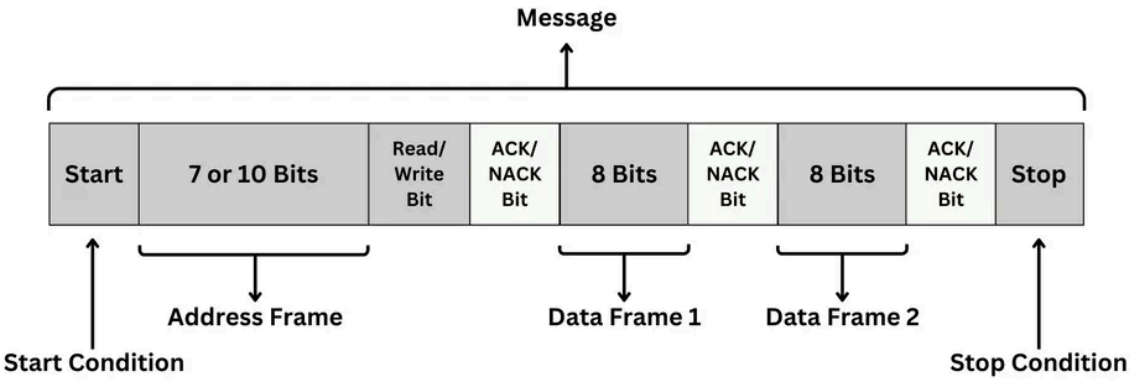
2. **Address Transmission:**The master addresses a slave by sending a 7-bit address followed by a read/write (R/W) bit—0 for write and 1 for read. All devices listen, but only the slave matching the address responds with an ACK (acknowledge) and participates in the communication, while others remain idle.



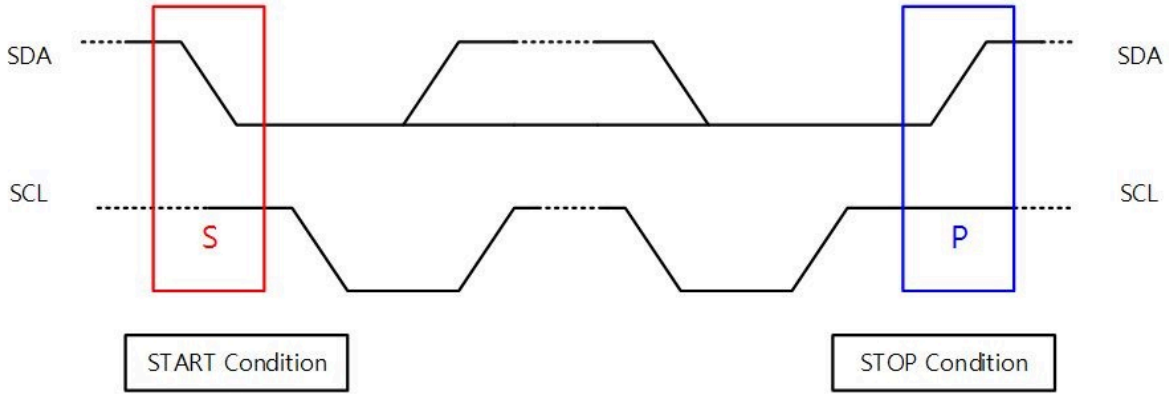
3. **Acknowledge Bit:**The acknowledge (ACK) bit is a signal sent after each byte of data to confirm successful receipt. After the master sends the slave address or a data byte, the receiving device (slave or master) pulls the SDA line low during the next clock pulse to send an ACK. If the line stays high, it's a NACK (no acknowledge), indicating the device is not responding or data transmission is complete. This mechanism ensures reliable data exchange between devices on the I2C bus.

4. **Data Transmission:**Once the master is ready to transmit data, it loads the information into an 8-bit data frame and sends it to the slave over the I2C bus. After receiving each byte, the slave acknowledges by pulling the SDA line low

during the next clock cycle, signaling successful receipt. The master then proceeds to send the next 8-bit data frame. This cycle of sending and acknowledging continues until all the data has been transmitted.



5 .Stop Condition: The stop condition marks the end of a data transmission and is generated by the master. It occurs when the SDA line transitions from LOW to HIGH while the SCL line is HIGH. This unique signal releases the bus, indicating to all devices that the communication session has ended and the bus is now free for other operations.



Advantages of I2c

- **Simple Two-Wire Interface** – Uses only SDA and SCL lines for communication, reducing pin count and wiring complexity
- **Moderate Speed for Short Distances** – Supports speeds up to 3.4 Mbps (High-Speed mode), suitable for many sensor and peripheral interfaces
- **Built-in Acknowledgment** – Ensures reliable data transfer with ACK/NACK bits after each byte
- **Addressing System** – Each slave has a unique address, allowing easy communication with multiple devices on the same bus
- **Low Power and Cost-Effective** – Ideal for embedded systems and battery-powered applications

Disadvantages of I2c

- **Short Distance Communication** – Not suitable for long-range communication due to signal degradation and noise sensitivity
- **More Complex Protocol** – Start/stop conditions, acknowledgments, and addressing make I2C more complex to implement in software compared to UART or SPI

- **Limited Speed** – Though faster than some protocols, I2C is slower than SPI, especially in standard (100 kbps) and fast (400 kbps) modes
- **Requires Pull-Up Resistors** – External pull-up resistors are needed on SDA and SCL lines, adding design complexity