Key Differences Between I2C, SPI, and UART Communication Protocols

Feature	I2C (Inter-Integrated Circuit)	SPI (Serial Peripheral Interface)	UART (Universal Asynchronous Receiver Transmitter)
Communication Type	Synchronous, multi-master, multi-slave	Synchronous, single-master, multi-slave	Asynchronous, point-to-point
Number of Wires	2 (SDA for data, SCL for clock)	4 (MOSI, MISO, SCLK, SS)	2 (TX and RX)
Data Transmission	Half-duplex	Full-duplex	Full-duplex
Speed	Up to ~3.4 Mbps (High-Speed Mode)	Faster than I2C, up to 100 Mbps	Limited by baud rate, typically up to ~1 Mbps
Number of Devices	Multiple (addressable via 7-bit or 10-bit addresses)	Multiple (each slave has a dedicated SS line)	Usually one-to-one (can use multiplexing for multiple devices)
Clock Signal	Required, generated by the master	Required, generated by the master	Not required (asynchronous communication)
Data Lines	Shared (SDA carries both addresses and data)	Separate lines for input (MISO) and output (MOSI)	Shared TX/RX for bidirectional communication
Complexity	Moderate (requires pull-up resistors on lines)	High (requires dedicated SS lines per slave)	Simple (only TX/RX lines needed)
Use Cases	Sensors (e.g., temperature, pressure), EEPROM	High-speed data transfer: displays, SD cards	Serial console, GPS modules, Bluetooth modules

Error Handling	Limited (ACK/NACK response)	No built-in error handling, depends on protocol	Basic error handling (parity, framing errors)
Power Consumption	Low	Higher than I2C due to multiple lines	Low
Master-Slave Relation	Multi-master capable	Single master	Peer-to-peer (no strict master-slave relation)